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THE 1933 SESSION OF THE SUMMER SCHOOL FOR ENGINEERING TEACHERS

By H. P. HAMMOND, *Director*

The 1933 session of the Summer School for Engineering Teachers will be devoted to mining and metallurgical engineering. This will complete the cycle of sessions that was begun when the Summer School was established in 1927. Since that year eleven sessions have been conducted and only mining and metallurgical engineering remain to complete the schedule of major divisions of the curriculum that was planned when the Summer School was inaugurated.

The session will be held at the University of Wisconsin beginning July 5. This date is immediately after the close of the Society's annual convention and of the meetings of the Founder Engineering Societies at the Century of Progress Exposition at Chicago. It will thus be possible for those who attend the Convention to go directly from Chicago to Madison for the Summer School.

R. S. McCaffrey, Professor of Mining and Metallurgy, University of Wisconsin, will serve as the Director of the session. Ben Elliott, Professor of Mechanical Engineering, University of Wisconsin, will serve as Secretary.

The group in attendance and the teaching staff will be housed in one of the University's dormitory units, where meals will also be provided. The dormitory is beautifully situated on the shores of Lake Mendota and provides excellent accommodations. Lectures will be held in the new quarters of the Department of Mining and Metallurgy. Both the University itself and the surrounding country provide exceptionally fine opportunities for recreation and sports, which have always been a feature of the out-of-hours portions of the Summer School programs.

The program of the session will be arranged in two principal parts. One, relating to subjects of importance to all teachers of mining and metallurgical engineering, will be common to all of those in attendance. The other will be arranged in two parallel divisions. One will comprise a series of lectures relating to mining engineering proper, including economic geology, petroleum engineering, and the like; and the other to the various phases of metallurgical engineering. The divisional meetings will be of immediate interest to teachers of the subjects mentioned.

The staff, as usual, will be comprised of the most eminent teachers and practising engineers of this branch of the profession.

The general plan and details of the program, as well as the selection of lecturers and discussion leaders, will be worked out in final form with the aid of a coöperative committee representing the Mineral Industries Education Division of the American Institute of Mining and Metallurgical Engineers. Director Charles H. Fulton of the Missouri School of Mines and Metallurgy is Chairman, and Professor Thomas T. Read of Columbia University is Vice-Chairman of the Division. The Coöperative Committee comprises Professors Thomas T. Read, of Columbia University, W. B. Plank, of Lafayette College, H. M. Boylston, of Case School of Applied Science, and James Aston, of Carnegie Institute of Technology.

The cost for those attending, in addition to travelling expenses, will be a registration fee of $10 and the cost of room and meals, which will be very moderate.

Those who desire to attend the session should address communications to the Director of the S. P. E. E. Summer School, 99 Livingston Street, Brooklyn, N. Y.

ARMOUR INSTITUTE OF TECHNOLOGY *

By ROBERT M. CUNNINGHAM, Jr.

Current literature reveals that there is an increasing tendency to-day to sum up past achievements, to review experiences. Institutions of all kinds, business, industrial, and social, are engaging in studies of their own activities, and of the fields in which their work is carried on. This is occasioned, undoubtedly, by the prevailing "Whither are we going?" attitude which the economic gloom of the last three years has induced. Our minds turn naturally to the past in an effort to gather some momentum with which to pierce the uncertainty of the future.

Whatever the sources from which this practice has arisen, it is an excellent discipline, and cannot be productive of other than good results. For while the past can never reveal the key to all present and future problems, we are always better able to search for their solution when we are thoroughly aware of our position, and of how we have come to it.

The past at Armour Institute of Technology goes back forty-one years to the fall of 1892, when the school was founded by Philip Danforth Armour. Already a great pioneer figure in middle western industry, Mr. Armour had a foreknowledge of the vital importance of technical progress in the development of industry. The accuracy of that foreknowledge has been proved historically. He recognized, moreover, the dual nature of the responsibility which attaches to any social institution; its obligation to the individual whom it trains, or protects, or punishes, or cures, as well as its obligation to the whole of the society it serves. The first public announcement issued by Armour Institute of Technology indicated the Founder's understanding of fundamental problems in education. "Its aim is broadly philanthropic," read this statement. "Profoundly realizing the importance of self-reliance as a factor in the development of character, the Founder has conditioned his benefactions in such a way as to emphasize both their value and the student's self-respect. The Institute is not a free school, but its charges for instruction are in harmony with the spirit which moves alike the Founder, the Trustees, and the Faculty; namely, the desire to help those who help themselves."

* Armour Institute of Technology will be host to the Society at its 40th anniversary meeting in Chicago, June 26–30, 1933. Meetings will be held in the Stevens Hotel.

Mr. Armour selected Dr. Frank W. Gunsaulus, minister of the Central Church in Chicago, to take active executive charge of the new college. As a matter of fact, Mr. Armour was first moved with the desire to establish such an institution when he heard Dr. Gunsaulus deplore the fact that so little was being done to prepare young people for the practical duties of life. Dr. Gunsaulus was president of Armour Institute of Technology for thirty years, and was responsible for much of the development which those years observed.

When instruction was first offered in September of 1893, four year courses were given in Mechanical and Electrical Engineering. It was during these years of the school's organization that Chicago was gaining recognition as a great center of architectural thought. The first "skyscraper" type of steel-framework building had been erected here in the 80's. The World's Fair of 1893 turned international attention upon Daniel H. Burnham and the brilliant young Louis Sullivan, both Chicagoans. In response to the widespread interest in architecture which these men and their work were stimulating, Armour Institute of Technology organized a department of Architecture in coöperation with the Art Institute of Chicago, Armour classes in Architecture are still conducted at the Art Institute.

Growth was rapid during the next four years, following the impulse for expansion of awakening industrial interests. In 1899, the course in Civil Engineering was organized; and in 1901, the course in Chemical Engineering. In 1903, the support of the fire insurance companies made possible the establishment of the department of Fire Protection Engineering. This department uses the facilities of the Underwriters' Laboratories in Chicago. Since 1920, representative students from many middle western states have been selected each year by the stock fire insurance companies, and awarded four-year scholarships in fire protection engineering.

Increases in size were the natural accompaniment of these early additions to the educational equipment of the college. The enrollment has increased steadily from a mere handful of entering students in the first class to the present student body of eight hundred and fifty, while the faculty roll now includes some eighty-five members.

A school's development, however, cannot be measured solely by its growth in equipment and enrollment. Always it is men who make the school, and always the most important events in its history are to be found in the works of the men who have guided its development. We cannot, of course, bring into this discussion any considerable mention of all the men who have made Armour history. There are, however, a few besides Mr. Armour and Dr.

Gunsaulus whose work has been of such an enduring character that no review, however brief, is satisfactory unless it includes their names. One such man, certainly, is Dr. Howard Monroe Raymond, who became president after the death of Dr. Gunsaulus in 1921. Dr. Raymond had been actively associated with Armour Institute of Technology for thirty-seven years when he was forced by ill-health to retire last June. He came to Armour as a young instructor in the Department of Physics in 1895, and was a vigorous influence in college affairs from the very beginning. He served a long and successful term of office as Dean, his thorough understanding of the student mind making him a capable and sympathetic counselor.

Another man who has been a powerful figure in Armour development is Professor George F. Gebhardt, Head of the Department of Mechanical Engineering. Professor Gebhardt, as a member of the original faculty, designed and built the building in which his department is located. He is widely known as an authority on power-plant engineering; his textbooks are used in technical schools all over the world.

Dr. Alfred E. Phillips, organizer and for years Head of the Department of Civil Engineering, Dean Claude Irwin Palmer, and Dean Louis C. Monin all spent long lives of service at Armour. Professor John E. Snow, Dr. George L. Scherger, Head of the Department of History and Political Science, and many others have had a quickening influence in the school's life. All have enjoyed long, forceful careers at Armour Institute. Their personalities, their energies, and their interests are woven inevitably into the fabric of Armour history.

Just as history is related in men and the events in which they have participated rather than in the records alone, so may the school's quality be revealed more largely in the aims and ideals of those men than in their accomplishment. To provide their students with a training in the application of scientific knowledge to practical use; to teach, in accordance with the wish of the Founder, the discipline of self-reliance and self-help; to bring the institution as a whole to a position of usefulness in the entire engineering scene of the middle west; such have been the objectives of the men who have guided the destiny of Armour Institute of Technology.

Such are still their aims. But the engineering and social scene in which we move is changing rapidly, and expressions of service in that scene must change also. Until recently, the college could be assured that its service was sufficiently valuable as long as it offered courses of training to provide the men for whom there was a considerable demand. The precipitous development of industry during the last two generations has naturally resulted in excessive

demands for men with all manner of special, technical training. These demands are reflected in the crowded curricula of many engineering colleges.

In the last few years, the retrenchment policies of industry have permitted pause for analysis of these demands and the ways in which they have been met. Such analysis reveals some unfortunate results of the rapid development and expansion through which industry has been passing. Any study of graduate engineers in industry—such a study, for example, as was conducted a few years ago by the Society for the Promotion of Engineering Education—must disclose the fact that many graduates occupy positions in other fields than the ones for which they were trained; that many who have followed their intended branches of engineering are not particularly well suited to them; that many who were educated for engineering capacities can never advance to higher than the trained-technician status, either because of personal limitations or because of the over-crowded condition of many engineering fields; and that almost all suffer to some extent for lack of extensive knowledge in other than engineering subjects.

The existence of these conditions cannot be said to constitute an indictment of engineering educational institutions. The very rapidity of industrial development is a testimonial to the service of engineering education, for that development has been engineering in character. And in such rapid expansion, there seemed indeed to be "room for everyone." Industry and the profession were absorbing vast numbers of graduate engineers. Enough of them progressed, and rapidly enough, so that there was no thorough criticism of the educational process from without. Educators themselves were preoccupied with detailed and complex problems of changing curricular content. Broadly critical attitudes could not be achieved.

Such an attitude was taken in the S. P. E. E. study of 1926–28, and today several schools are taking time to apply the methods and results of that study to their own specific problems. At Armour, a thorough study has been made of the Chicago industrial area, which under normal circumstances has absorbed approximately seventy-five per cent of Armour graduates, for the purpose of determining how the educational program might be made to correspond more closely to the needs which it seeks to fulfill. Out of that study a plan for development has evolved, a plan which should serve to increase the usefulness of the school in future years, and to make impossible the re-occurrence of past mistakes.

Not by any means complete in its detail, the plan points in broad outline the direction in which development must lie. Curricular revisions are being worked out in response to the universal demand

for a graduate engineer with a broader knowledge of the humanities, and of economics, sociology, and psychology. Any curricular adjustment must be accompanied by the most scrupulous attention to teaching method. These are not measures to be decided and executed forthwith. Step must follow considered step. In many cases the trial and error method alone can establish the efficacy of change. With the opening last fall of the new Department of Science, offering a four-year course in fundamental science and humanistic subjects with a few engineering options, the first important step in the new program was definitely taken.

The nature of the program, moreover, is elastic. The years to come may bring as much of change as have the ones just gone, and therefore no sound educational policy can long be static. Recommendations for procedure at Armour Institute include the establishment of permanent channels of expression between industry and the school, through which a constant process of analysis and adjustment may be effected. The particular agencies through which these objectives will be sought are found in an enlarged Board of Trustees, including representative members from all important industrial and commercial interests in Chicago, and in an extensive department of personnel records, which will keep careful check on the progress of graduates as a constant critique of educational methods.

Ultimately, the program contemplates organization of two separate institutions whose work is closely allied with that of the engineering college. These are a technical institute—to be established with precisely those objectives defined in the S. P. E. E. study—and an institute of industrial research, similar in function to the Mellon Institute at the University of Pittsburgh. While this ambitious program may not be realized for some years to come, it is planned, as have been adjustments within the college, to meet the manifest demands for such services.

Dr. Willard E. Hotchkiss, who was elected to the presidency of Armour Institute of Technology in January of this year, directs the working out of operating problems in this new plan. President Hotchkiss came to Armour Institute from New York, where he was a member of the Economics staff of New York University, while engaged in research with the New York Building Congress. He organized and was for several years Dean of the School of Commerce at Northwestern University. After being in business for a few years, he was called to the Pacific Coast to organize a Graduate School of Business at Leland Stanford University, of which he was Dean until 1932. Industrial and engineering leaders, and educators who have had an opportunity to work with Dr. Hotchkiss are confident that under his guidance the plans herein outlined can-

not fail to develop a more useful institution, more accurately adjusted to the demands placed upon it by the engineering professions and industries represented in this area.

Armour Institute of Technology is by no means alone in undertaking such a project. Programs with similar objectives have been laid down at colleges and universities throughout the country. Differing widely in detail, these programs all strike at one recognized weakness in higher education, that which was well expressed some time ago by Dean Hawkes of Columbia University when he said, "There is no doubt in my mind that the American college has failed more signally in relating the student's education to the kind of life he is going to live than in any other direction."

No one can foretell what the next few years will bring. We live and work in a period whose most consistent characteristic is rapid change, change affected by such a variety of circumstance that it is impossible to prophesy even its direction. There can be no doubt, however, that education will play an important part in the solution of social and economic problems. The program at Armour Institute of Technology embodies a sincere effort to reveal and cope with those of the problems which lie within the sphere of engineering education. To keep following the course which was charted forty years ago by the Founder, and to keep correcting that course by consideration of shifting social winds—such is the task of Armour Institute of Technology.

THINGS THAT ARE COMMONLY WRONG IN TEXT BOOKS ON MACHINE DESIGN

By W. TRINKS

Professor of Mechanical Engineering, Carnegie Institute of Technology

Practically all of the text books on Machine Design contain several formulae that benumb the reasoning power of the student. While in applied mechanics and in the theory of materials the student is acquainted with the effects of deformation, he is, in machine design, frequently asked to disregard elastic deformations entirely.

A few examples will illustrate what is meant.

In the study of bolts and nuts the student is told that the pressure per square inch of screw thread is found by dividing the load by the number of threads in the nut and the projected ring area of each thread. In other words, the assumption is made that the pressure is uniformly distributed over all of the threads in the nut.

A short reasoning shows that, as a rule, this assumption is far from right. In Fig. 1 the bolt has been replaced by a bar with

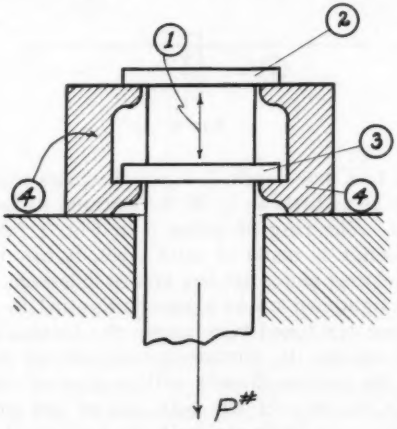

Fig. 1.

two collars and the nut has been replaced by a sleeve with two collars. From Fig. 1 it is immediately seen that, if each of the collars 2 and 3 carries one half of the load, part 1 of the bar is in

tension and part 4 of the nut is in compression. In consequence, 1 becomes longer and 4 becomes shorter, which means that collar number 2 of the bar will lift away from the corresponding collar of the nut. It is therefore quite obvious that collar number 3 carries all of the load and that collar number 2 stays in contact with the sleeve, without carrying any load, as long as we do not exceed the elastic limit anywhere.

If we carry this reasoning to its logical conclusion it follows that in an ordinary bolt and nut only part of the first thread can bear.

In contrast with this reasoning it is known from practice that a certain length of nut is necessary; the question then arises how the two statements can be reconciled.

Returning to Fig. 1, it will be seen that if the force P is gradually increased, collar number 3 will bend or even be partly sheared (plastically displaced) to such an extent that collar 2 can begin to take some load. It must be remembered that when a bar is sheared as indicated in Fig. 2 the original depth of the bar 1–4

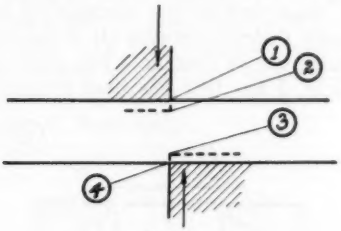

FIG. 2.

can be reduced to a new depth, 2–3, which varies with the material and which may be as little as ⅓ of the original distance 1–4 before the bar lets go. Shearing of collar 3 in Fig. 1 follows the same laws. If the collar is made of mild steel, it can be shoved one-third of its thickness along the bar before it lets go.

If a nut is tightened up or a load is applied to a bolt the nut of which was not tightened very much, the bottom thread, that is to say the one nearest the abutment, will take all the load; if the load increases the bottom threads will be sheared (shoved without rupture) along the axis of the bolt and of the nut. Successive threads will then take their share of the load until with sufficient tightening all of the threads carry.

It follows immediately that if a screw carries a heavy alternating load, the bottom screw threads must be sheared back and forth on the bolt and nut and will crumble off unless made of extra soft

and ductile material. Such action has been observed in the threads of piston rods.

The simple reasoning of Fig. 1 also explains why threads in cast iron are not as reliable as threads in a more ductile material. The bolt used in a cast iron nut should be of extremely soft and ductile material.

Those who can think quickly will have concluded that the uneven distribution of load comes from the fact that in Fig. 1 the part representing the bolt is in tension while the part representing the nut is in compression. The question arises whether plastic displacement of the threads along the axis of the bolt is necessary for producing uniform pressure between nut and bolt if both bolt and nut are in tension. Fig. 3 shows such an arrangement. Let

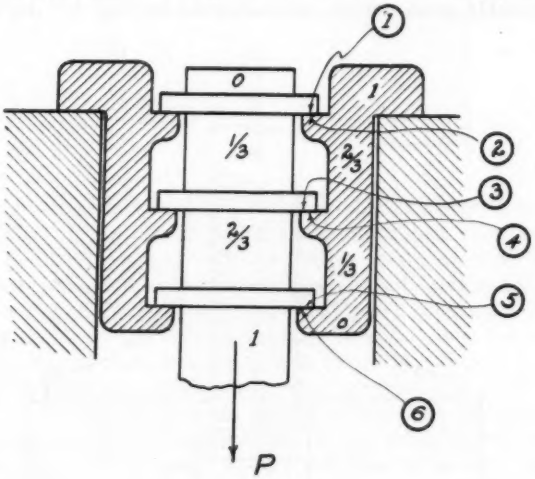

FIG. 3.

it be assumed that each of collars 1, 3 and 5 bears ⅓ of the total load P. Then the force distribution in the bolt and in the nut is indicated by the figures, 0, ⅓, ⅔ and 1, which are fractions of the total load P. It will be seen that the upper section, 2–4, of the nut stretches more in comparison than the corresponding section, 1–3, of the bolt, while the lower section 4–6 of the nut stretches less in comparison than the corresponding section, 3–5 of the bolt. The result of this difference of stretch is that collars 1–2 and 5–6 remain in contact while collars 3 and 4 part company, because the upper part of the nut stretches more than (and away from) the upper part of the bolt.

The upshot of this reasoning is that with the bolt in tension it is better to have the nut in tension than in compression if greatest uniformity of pressure distribution between bolt and nut is desired. If the bolt is in compression the nut should also be in compression. If the load is heavy the upper and lower threads are displaced plastically along the bolt or along the nut and the pressure will become uniform. It must, however, be realized that the pressure cannot become uniform until it has been so heavy on the outer threads that shearing motion occurs. The shearing displacement can be avoided if wear takes the place of shear. By sufficiently great wear, pressure can also be made uniform.

If absolute uniformity of pressure throughout the length of the nut is to be obtained under any condition of loading, the nut must have variable cross section, as indicated in Fig. 4. An equation

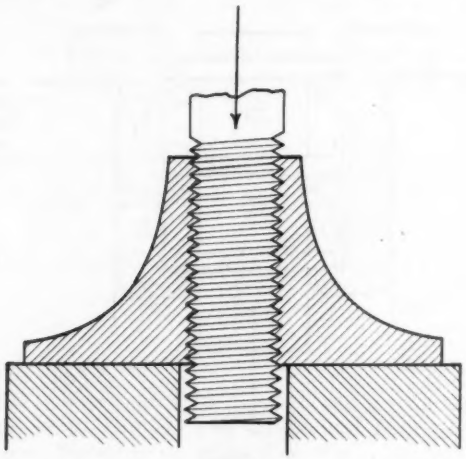

FIG. 4.

for the correct outline of the nut was given by Timoshenko (Applied Elasticity, example 9).

Constant-thickness nuts which transmit motion under heavy pressure are subjected to a great deal of wear. It is remarkable that so far nobody has used nuts of variable thickness for cases of this sort. They certainly should help to reduce wear. In each case the nut should be in tension if the bolt is in tension and the nut should be in compression when the bolt is in compression.

It is admitted that lubrication is also an essential factor. A long, variable thickness nut, improperly lubricated will wear more than a well lubricated, constant-thickness nut.

Wrong conclusions are frequently drawn concerning the holding capacity of press and shrink fits, because elastic deformations are neglected. If a heavy hub is either pressed or shrunk on a shaft as indicated in Fig. 5, it is commonly assumed that all parts

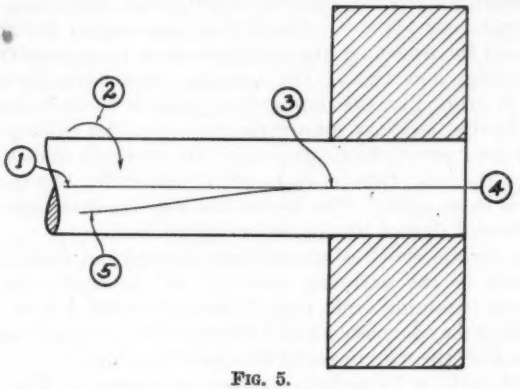

FIG. 5.

of the contact surface between hub and shaft take part evenly in the transfer of torque. A brief reasoning shows that this supposition is utterly wrong. If the torque is transmitted through the shaft as indicated by the arrow 2, an initially straight line, 1–3, drawn on the surface of the unstrained shaft becomes a helix as shown by 5–3. In the hub an initially straight line, 3–4, remains a straight line if the press or shrink fit holds. But if torque is transmitted through a shaft, an initially straight line must become a helix which means that no torque whatsoever is transmitted through the length 3–4 and that all of the torque passes into the hub from the shaft at point 3, just the same as would happen if the hub, 3–4 were infinitely short. Again we know from practice that an infinitely short hub will not do, and it behooves us to find a way for reconciling the two conflicting facts.

Evidently no shrink or press fit is strong enough to allow the passing of all of the torque in an infinitely thin layer in the plane 3. What happens is that the shaft slips in the hub at point 3 and that the torque is transmitted in the same way in which it is transmitted if we twist a cork in the neck of a bottle. It is quite possible that the bottom of the cork does not move in the bottle, but we can readily see through the glass how the top of the cork twists. No harm is done by this method of transmitting torque if the torque is almost constant and is always in the same direction, because the parts with initial relative motion between the shaft and the hub

transmit torque just the same as a friction clutch does. If, however, the torque comes close to the carrying capacity of the shaft and is very variable or, worse yet, is alternating such as it is for instance in a reversing rolling mill, then and in that case the continued relative twisting motion between the shaft and the hub causes wear near plane 3. The hub is loosened on the shaft near plane 3 and the loosening gradually proceeds from point 3 to point 4. No matter how tightly the hub may have been shrunk on or pressed on originally, the time arrives when it becomes loose on the shaft. At that time the master mechanic gets his calling-down for having done a poor job of shrinking. He probably makes a greater allowance the next time so as to get a tighter fit, but in due time the hub is loose again. The longer the hub (in direction 3–4), the longer the evil day of coming loose is postponed.

If the torque which is transmitted through the shaft is small in comparison to the carrying capacity of the shaft, the gradual progressive loosening from point 3 towards point 4 is so slow that the machine may be obsolete and scrapped before the loosening has progressed all the way towards the end of the hub.

A hub with a hyperbolic outline as shown in Fig. 6 allows

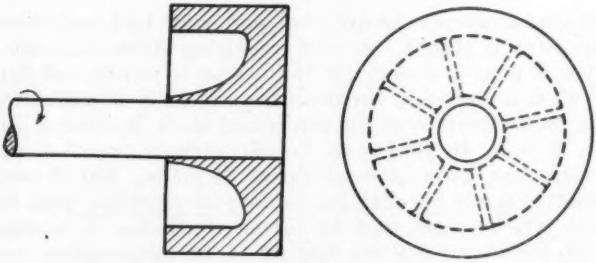

FIG. 6.

gradual transfer of the torque from the shaft into the hub. A hub of this type was advertised in a German trade paper in December 1932. Pressing or shrinking can be made possible by using a number of ribs which transmit the force from the heavy outer hub to the hyperbolic inner hub as indicated in the illustration.

The reasoning which was applied to Figs. 5 and 6 can now be transferred to the keyed connection shown in Fig. 7. In text books the shearing stress in the key and the compressive stress between key and shaft on one side and key and hub on the other side are commonly computed in the following manner: The torque is divided by the radius of the shaft whereby the tangential force at the periphery of the shaft is found. This force divided by $l \times W$

(Fig. 7) furnishes the shearing stress in the key and the same force divided by $l \times S$ furnishes the compressive stress between the key and shaft on one side and the key and hub on the other side. By comparison with Fig. 5 we realize that elastic deformations (coupled with the rigidity of the hub) make this uniformity of transfer of torque utterly impossible. Practically all of the torque is transmitted at or near point 3 and practically nothing at or near point 4. The shearing stress in the key near point 3 is

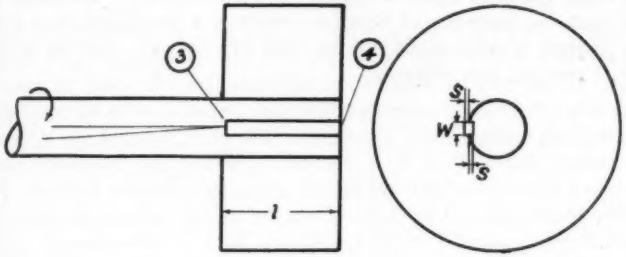

FIG. 7.

very great and so is the compressive stress. As a matter of fact, the materials of the hub, the key, and the shaft become crushed near point 3 (for heavy torque) and it is only by this crushing action (coupled with a slight plastic shearing of the key) that any stress can be carried by the key away from point 3 over towards point 4.

Again we can reason the same as we did in connection with Fig. 5 that no harm is done by this action as long as the shaft is not stressed up to or near its elastic limit. If we stress the shaft very highly and if we transmit highly variable or alternating torques, the crushing action on the key, shaft, and hub becomes so great that the hold of the key is loosened at or near point 3. In severe cases such as in reversing rolling mills, the crushing of the key gradually proceeds from point 3 towards point 4, the same as it does with a press or a shrink fit, and finally the key becomes loose. The author has seen engineers and mechanics stand around the loosened parts in a case of this sort and wonder what in heaven or earth made the well fitted hub come loose in spite of all precautions in the fitting of keys and of excellent work in the press and shrink fit. The automobile industry has coped with this problem by the use of splined shafts.

From these brief remarks it will be seen that most machine design text books are negligently written and misleading. They should take the non-uniformity of stress distribution into account

and should state that there is a relation between permissible stress in the key and length of hub in comparison to the diameter of the shaft. The longer the hub the smaller must be the shearing stress in the key or the pressure between the key and the hub.

These examples could be multiplied and could be extended to riveted joints, bearings and many other elements of machines, but the examples here given will suffice. It is hoped that the writers of machine design texts will take this matter under consideration and teach the boys to see things as they actually are. Someone has said that the Bachelor of Science degree is a certificate that a boy has learned a good many things that are not so. Let us do our best to remedy this situation.

REQUIRED COURSE IN MACHINE DESIGN FOR NON-MECHANICAL ENGINEERING STUDENTS *

By R. H. G. EDMONDS

University of Washington

A study of the curricula of a representative group of American engineering colleges reveals the fact that there is considerable difference of opinion regarding the importance of courses in design. This is more particularly true with reference to machine design as given to students outside the Mechanical Engineering department. The purpose of this paper is twofold; first to show the desirability of a required course in machine design for non-mechanical engineering students and second to emphasize some of the important factors in the presentation of such a course. What I have to say is based largely on experience in teaching such a source at the University of Washington.

During the last 15 or 20 years there has been a gradual turning away from courses in design. This is apparently due in a large measure to the demand for specialization. The amount and variety of such specialization as provided for in the modern engineering school curriculum is astounding. Along with the standard courses in civil, electrical, and mechanical engineering, many institutions, through a grand array of options and sub-options, offer specialized training for as many as 25 or 30 different engineering careers. Such an arrangement is possible only through the elimination of some of the fundamental courses, among them machine design.

In my opinion, highly specialized education cannot bring the best results for two reasons. In the first place much of the information given in the special course is out-of-date and obsolete before the student has a chance to use it. And in the second place it is impossible, except in a very few cases, for a student to tell within such narrow limits what course he should take. We can all name many examples of men who have won distinction in fields of engineering endeavor far removed from those covered in their academic training.

Dr. Harvey N. Davis in his address on the occasion of his inauguration as President of Stevens Institute of Technology criticizes this tendency toward specialization very severely. His con-

* Presented before the Machine Design Section at the Corvallis meeting of the S. P. E. E., June 29–July 1, 1932.

ception of the educational opportunity which the undergraduate engineering school of to-day would do well to offer their students is briefly expressed in the following quotation from his address. "There will not be a multiplicity of more or less specialized undergraduate curricula, each designed to train for some one variety of engineering career. There will be one curriculum. And in this curriculum the emphasis will be placed on the basic disciplines that underlie all engineering careers; there will be plenty of mathematics, physics, and chemistry; there will be mechanics in all its branches, including the deplorably few fundamental principles that are yet known as to the nature and serviceableness of the materials of engineering."

Dr. Davis is rather an extremist in this regard and I am not ready to agree completely with him in his desire for one engineering curriculum. However, I do feel very strongly that we should confine ourselves to a few broad engineering courses covering the fundamentals and so designed as to develop truly educated leaders rather than trained technicians.

There are three reasons why Machine Design should be considered as a fundamental and basic course and be required of the non-mechanical engineering student as well as the one majoring in mechanical engineering. First, the facts and information presented in such a course are desirable for all engineers. It may be rather trite, yet it is nevertheless true, that machines play an important rôle in all engineering operations and a knowledge of the principles involved in their design is highly desirable if not absolutely necessary. Of course the electrical engineer, the chemical engineer, the mining engineer and even the civil engineer will be interested in the design of special machines but in every case the mechanical features are of basic importance and must be considered.

It should be said at this point perhaps, that we, as teachers of machine design, cannot hope to make designers in the college classroom. Such a goal is reached only through a long period of acquisition and training after college. As in most other courses, the purpose of the machine design course should be to assist in the laying of a broad educational foundation on which the young engineer can build a successful career.

Second, the course in machine design provides instruction and experience in constructive planning. It gives the student an opportunity to exercise his imagination. It fosters and develops creative ability. By virtue of the nature of the problems with which he is confronted, the student is required to focus all the knowledge and practice that he has obtained in engineering physics, analytical mechanics, strength of materials on a concrete task and then carry that task to completion.

Third, machine design provides excellent mental training. Systematic drill in the processes of analysis and synthesis as they are applied to simple machines or machine elements is fine practice in that highly desirable art of clear thinking. Here, the instructor has a wonderful field for developing logical methods of reasoning. The student may be taught when and where to place reliance upon analytical methods completely and when it is necessary to exercise practical judgment. More advanced problems will require that he formulate his own method of attack, carefully examining and checking his conclusions in the light of the best information at hand.

C. A. Norman in the preface to his text on Machine Design very aptly says: "There is a growing realization of the fact that more engineering thinking, more keen analytical reasoning on the basis of fact, is urgently needed, not only in industry, but in our public affairs and in our social life generally. The student must get some idea of how engineering and scientific advance is achieved, of the struggles and controversies involved, of the correlation of mathematical and experimental fact, of the straining of one's mind to the utmost to penetrate a complicated and abstruse situation."

It is questionable, of course, how much of the spirit of true engineering achievement can be imparted in an elementary course in machine design. In its broader aspects, however, it may be conceived to aid materially in imparting the principles of constructive thinking and engineering creation generally. The majority of engineering curricula offer too few opportunities for such training.

Evidence of the high regard that professional engineers have for academic training in design is found in Bulletin 13 of the report of the S. P. E. E. investigation of engineering education. This report is based on questionnaires sent out through the several professional engineering societies including A. S. M. E, A. S. C. E., A. I. E. E., A. I. M. & M. E., and A. I. Ch. E. The part of the report in which we are interested at this time is that which gives the tabulation of replies to the following question. Which of the several divisions of ———————— engineering (insert the branch of engineering desired) do you consider of such importance as to warrant their inclusion in the training of all ———————— engineers? This question was one of a number. The replies are quite interesting. In mechanical engineering, machine design heads the list. In chemical engineering, chemical plant design is first with chemical machinery design next. In electrical engineering, electrical machine design was third in importance as indicated by the replies of those answering the questionnaire. In mining engineering, courses in mine machinery, in hoisting and transportation are well toward the top of the list. In civil engineering, while a number of design courses are given mention, these have little or no dependence on

machine design. It should be made clear that statements made above with reference to design courses in chemical, electrical, and mining engineering refer to specialized courses in design in that department. However, it must be conceded that such design work has definite mechanical features and the student can best prepare himself for such work by taking the course in machine design given in the mechanical engineering department.

It is also of interest to note in Bulletin 16 of the same report entitled "A Comparative Study of Engineering Education in the U. S. and in Europe," how frequently courses in the Theory of Machines and Machine Design are mentioned in the discussion of curricula of engineering schools in Europe and Great Britain.

I have thus far drawn a rather idealistic picture of the possibilities to be attained in this course in machine design. None of you know better than I do how important a part the instructor and his method play in the giving of a satisfactory course and how often he falls short. It is his duty, however, to strive for that ideal and to try to approach it although he may never quite reach it.

In the second part of my discussion, I do not hope to cover the whole field of method as it applies to machine design but rather to point out some of the more important factors regarding the course and the method of presentation.

As to the course content, any outline that I would give would be rather conventional, more or less of a restatement of the items appearing in the table of contents of a good text on the subject. The course would necessarily be general and somewhat elementary, but should not be given earlier than the junior year and should be preceded by a good course in mechanics and strength of materials. When possible the mechanical and non-mechanical students should be segregated and be given different courses. Where this is not possible because of low enrollment or other cause the mechanicals should be given an advanced course in the senior year.

For the purpose of discussion, let us divide the work of the course into three parts, (1) Theory, (2) Computations, (3) Machine Drawing and Lay-out.

There probably is some difference of opinion as to the amount of time that should be put in on theory. I am a very strong believer in the student knowing the why and wherefore of all the equations that he uses. I have little sympathy for the so-called empirical design course that still persists in some curricula. This might better be called advanced mechanical drawing. The student should be taught to use handbooks with caution and intelligence. The empirical formula may be necessary at times but its origin should be carefully checked to make sure that it applies to the case

with which you are concerned. Most of the rules-of-thumb and tables of proportions have no place in a real design course.

The question arises as to how best to impart theoretical information. With reference to lecture work in machine design, I am inclined to apply what Professor Moore of Illinois expresses as his opinion in regard to this matter in connection with work in engineering materials. He says, "Most of the information about materials and the careful statement of such general principles as there are can, in general, be given better by the printed page than by word of mouth."

Of course, some explanation of theory must be made by the instructor but this should be in the nature of short informal discussion preceded by the study of an assignment in the text and accompanied by concrete applications in the form of numerical problems.

Personally, I have not found oral recitation work particularly valuable or desirable in the machine design course. Ability to express one's self orally is as highly important in engineering as in other lines of endeavor but the time is far too limited to give every individual adequate practice.

The greater emphasis in the course should be placed on written computation. At first the problems should be simple and short but carefully chosen and directed. Problems in analysis involving the calculation of unit stresses and safe loads should be used as well as design problems. Such computations are best made under the supervision of an instructor during a laboratory period. All work done by the student should be carefully checked by the instructor or his assistant for accuracy in reasoning and judgment as well as in mathematics. The papers should be returned to him with comments from the instructor and the student given time for making corrections. A little ground well covered is better than a larger field poorly mastered.

From time to time more complete design problems should be given. Information regarding this work should be given in the form of a specification. The student should be guided and directed rather than driven. His initiative and creative genius should be stimulated. He should be encouraged to think for himself, to analyze a given situation, to break it up into simple elementary parts to which he can apply his theoretical knowledge.

For a number of years, we have given as the final problem in the course at the University of Washington the design of a bucket elevator. In addition to a specification telling him the general information about the design, the student is furnished with a manufacturer's catalog, giving complete information regarding buckets, chain, sprockets, etc. The student is required to make a

complete design including the choice of a driving motor and the design of a connecting transmission. I have found this to be an excellent exercise. It arouses the student's interest and the quality of his work is thereby improved. The study of the catalog is in itself a valuable piece of work. It enables the instructor to point out in a very practical way the value and the necessity of standardization. In general, this problem calls forth his imagination, draws on his skill, judgment and experience without limit.

In my opinion, the time spent in drawing should be reduced to a minimum. The rudiments of mechanical drawing will have been covered already in a preliminary course and there is insufficient time for any great amount of additional practice. Some drawings should perhaps be made in the longer design problems. These should be made in pencil on vellum paper and blueprints made from them. This may require some special instruction not gotten elsewhere and is worth while. Some practice and instruction should be given the student in freehand sketching. Ability to make a usable sketch without a straight-edge or drawing instruments is often lacking in the practicing engineer. A few exercises of this kind are desirable and in addition the student should be encouraged to use frequent sketches in his computations. Drawings in the form of layouts are often a very necessary part of some design work such as cams, rachets, etc. Some practice in this would be to the point if time permits. Long drawnout operations in the form of drawings and tracings should be eliminated and the time used to better advantage.

In closing, I should like to quote a paragraph from an address by Mr. J. C. Parker, vice-president of the Brooklyn Edison Co. Under the rather peculiar title "Wanted: an Unpractical Education" we teachers of engineering find much food for thought. In the course of his discussion, this captain of modern industry makes the following plea: "We need young men of keen perception, sound and orderly analytical ability, of sympathy and of understanding, to analyze facts as they arise from day to day, to draw new conclusions into canons of the truth, and to devise new practicalities of putting them into effect. This sort of thing in that it pays big dividends or increases the social value of our service is practical with a vengeance, and it is the sort of thing for which every industry and every profession and art is ahungered and athirst whether it recognizes the need or not."

In my opinion, training in machine design can be made to contribute largely in the preparation of young men to meet the requirements of Mr. Parker, or of any other engineering executive, regardless of the particular field of engineering concerned.

POWER OF EXPRESSION AND THE IMPORTANCE OF DEFINITIONS IN THE TRAINING OF THE ENGINEER

By W. E. HOWLAND

Assistant Professor of Civil Engineering, Purdue University

There are two important reasons, as I see it, why the engineer does not write and speak often and effectively. First, he does not receive as much training in writing and speaking as do members of other professions—as do lawyers, for example. He must learn to think and express his thoughts not only in words but also in pictures, as in drafting, and in symbols, as in mathematics. The lawyer, on the other hand, uses words almost exclusively.

Secondly, his education, insofar as it consists in clear thinking, disqualifies or at least dissuades him from the kind of speech-making and writing which is always so largely in vogue. I refer to decorative but inconsequential platitudes and inaccuracies illogically but plausibly deduced. A mind trained not to deceive itself is not inclined to deceive another.

In considering the inarticulateness of the engineer we should keep these two facts in mind. Necessarily he may not receive as much oral and written training in school as many other students. Necessarily many of the subjects of discourse and methods of reasoning considered and employed by lawyers, politicians, theologians, and others are not open to him or not to his taste. And we do not wish to make them so. We do not want him to add to the confusion of thought. If, like others, he has no clear ideas on a given subject to express, it is better, far better, that he remain silent.

When we examine his training it appears doubtful that more time can be devoted in the curriculum to formal courses in English to improve his facility in the use of words without at the same time endangering the value of other disciplines of equal importance. The only improvement possible seems to be in making more effective such courses as are already in the curriculum in the direction of clarity and precision and other like faculties in the use of language, not inconsistent with the ideals of an engineer's training. This dictum would exclude practice in sophistry from such courses as public speaking. Effectiveness in expression attained at the expense of logic and accuracy must be relinquished.

The improvement, which I have in mind, might conceivably be attained not only in courses in formal English but also in "Applied

English'' as laboratory reports, seminars, and even, as I shall indicate, in such a course as hydraulics.

There are very definite engineering uses for the power of clear thinking in speech and writing. One of these is the need for translation of the meaning of a symbol or a drawing or of an idea however expressed into words, *i.e.*, definition. The power of definition is more than a mere art of expression—it involves the very essence of the act of thought itself. Dr. G. C. Brandenburg of our (Purdue) staff has formulated and, in a measure, proved the theory that language and thought are very intimately connected in grade school learning.[1] I should like to affirm that the same is true in acquiring the essentials of such a course as hydraulics. I have just a little experimental proof, or perhaps I should say, an illustration, of this assertion from our last final examination in hydraulics. I correlated the grades of 97 students in a single question, one of eight, on definitions with the total grade on the examination which otherwise consisted of numerical problems. The coefficient of correlation was 0.46. The probable error was 0.015 so the results are statistically significant.

This appears to mean that there is a very real relation between ability to state ideas clearly in words and the ability to use the ideas in solving numerical problems. This, of course, is what would be expected. If one cannot think clearly in words then he probably cannot think clearly in numbers or in symbols or drawings.

I think we teachers of mathematical subjects are likely to believe that the graphical or numerical parts of our courses are all important. As a matter of fact, many of the difficulties of the students arise from a faulty understanding of basic concepts and terms which in turn arises from a failure to understand and to express in words the statement or definition involved. For this reason, if for no other, I am in favor of the recitation method of instruction in small classes where the student is called on frequently to embody his knowledge in words—even in so mathematical a course as hydraulics and I am inclined to think that if this practice were consistently followed in all engineering subjects not only would the knowledge of the subjects themselves be made more profound but a very creditable power of expression would be developed.

[1] ''Psychological Aspects of Language,'' by G. C. Brandenburg, *Jl. Ed. Psychology*, Vol. 9, 1918, p. 313.

THE CASE METHOD IN UNDERGRADUATE TEACHING *

By ERWIN H. SCHELL

Professor of Business Management, Massachusetts Institute of Technology

A business case is an educational utensil. Intrinsically, it has little value. As a tool in the art of teaching, however, its worth is only beginning to be evaluated. Like all tools, its use must vary in terms of the subject to which it is applied, and in terms of the specific objective sought.

This paper aims to contrast the use of the business case in classes of Junior and Senior undergraduates with classes of first-year graduate students. In both instances the dominant objective has been to train the student in forming sound business judgments. Secondary objectives have been the development of business principles and the imparting of knowledge concerning business elements and their organization.

Student Attitude

The first-year graduate student sees himself at the beginning of a new cycle of experiences. He is curious, interested, eager, apprehensive. He has heard a good deal about the school; he has been stimulated by his new environment and associates. He usually has a keen personal desire to be of practical use in the world. He is interested in anything which may be used to later advantage. He is anxious to succeed. Although he doesn't know just what success is, he feels that somehow he must make good. He fears that he may be wasting his time. Many of his classmates are already in business, accumulating practical experience—getting a start. He is told that he will go farther in the long run with additional study. He hopes but questions.

The Junior or Senior undergraduate student sees himself nearing the end of a long cycle of educational experiences. He is increasingly curious and concerned about his first job and the realities of the world outside; and his educational activities are directed to the end that he can get out. This attitude does not imply that he shirks his work; for the diploma is a very effective form of incen-

* A lecture delivered at the Economics Session of the S. P. E. E. Summer School for Engineering Teachers, Stevens Institute of Technology, July 18, 1932.

tive. His tendency, however, is to conform his initiative to requirements of which the fulfilment brings release.

The undergraduate, then, finds satisfaction in his approach to a goal which is established by his teachers. The graduate finds satisfaction in an ever present conviction that he is increasing his powers. The undergraduate is watching the mileposts, the graduate the speedometer.

These contrasting attitudes affect the teaching method in a fundamental way. With undergraduates, the work must be laid out. With graduates, it needs only to be held out. In the first case, the teacher assigns; in the second, he supplies. For example, in undergraduate teaching it will be necessary to require collateral readings where informative background is necessary to the effective consideration of a case, and such work can only be assured through the knowledge that periodical quizzes or examinations of a formal nature will take place. Graduates, given suitable bibliographies, will search out such information without further direction or verification. Likewise, in the use of preparatory questions requiring written answers, the undergraduate will desire a class mark on his work; while the graduate, if assured that his work will be constructively criticized, prefers no formal record.

Student Background

A crude classification of student background might divide students into those who have previously specialized in technical, economic and liberal arts subjects. These early selections are indicative of natural bent. The technical courses frequently acquaint the student with machinery and machine processes. This experience, coupled with his tendency to be interested in such matters, gives him a definite leaning toward business problems relating to production. In a course which has been given in a form allowing joint presentation of marketing and production, it has appeared that the members of the class most interested in technical subjects were likewise most interested in production. It seems to be fairly clear that the students who are predisposed to liberal arts subjects show a greater interest in problems of marketing, as both of these fields have strong humanistic emphasis. There seem to be some grounds also for believing that students who enjoy the more abstract sciences, such as economic theory, find greatest appeal in problems of finance.

The graduate group is conglomerate. This condition would hamper teaching effectiveness were it not for the fact that one of the fundamentals of training in business judgments is the development of a facility in making use of the group mind. Student group conferences are urged; and, in the intermixing of type and

background and consequent opinion prior to individual decision, a breadth of view is obtained which is valuable not only in aiding accuracy of judgment but also in emphasizing the value of such differences in enriching group discussion—a resource of which business men are hesitant to make use. Therefore, it is distinctly unwise to attempt any division of graduate students into technical, liberal arts or economic groups for teaching purposes.

In undergraduate teaching, it is probable that the class will contain a dominating proportion of one of the three types. In such event, it is important that teaching emphasis be so directed that an ultimately balanced perspective will result. For example, in a class of engineering students, it is important that the relationship of production problems to those of finance and marketing be constantly stressed in order that the student be not led to assume that production is of dominating significance in industrial success.

Student Approach

None of the three backgrounds mentioned seems to offer an entirely satisfactory basis for business thinking. The technically trained mind is rendered almost helpless by the obvious lack of complete data—a condition which is characteristic of the business problem. Furthermore, it tends to disregard or weigh too lightly the influence of the psychological factors involved, and is given to precise and usually well organized analysis on a basis of an incomplete grouping of elements and without an imaginative grasp of possibilities.

The liberal arts training rarely provides the student with an analytic thinking method suitable for the solution of business problems. The approach is essentially speculative and in cases where balanced reasoning is called for the student does not know his tools. On the other hand, such a mind is alert, inquisitive, and has a wealth of subconscious opinion, and if given a chance to mull, frequently arrives at conclusions whose brilliance is measured by their simplicity.

The abstract type of mind rarely senses the significance of the time factor in the solution of business problems. Its thinking is essentially static, and it must be stirred to the importance of the ultimate use to which its decision will be put. It further tends to rely upon authority and theoretic principle and to hope for solution through the dicta of past wisdom, rather than through a careful construction of personal reasoning.

Student Response to the Case Method

The graduate student anticipates some variety in methods of graduate instruction when contrasted with his undergraduate ex-

perience. Hence a change is welcomed. Indeed, in a school where the case method is the rule rather than the exception, its use becomes imperative to the maintenance of student morale.

The undergraduate in the upper classes looks upon a new teaching method only as a new and different form of hurdle. He has grown facile in the giving of maximum satisfaction for minimum effort under orthodox teaching methods, and a change of approach is negatively rather than positively received. On the other hand the great appeal of the upper class course is found in the quality of practicality; and the case, with its atmosphere of reality and its promise of preparedness, has strong advantages in the eyes of many students.

Practical considerations make it rarely feasible to change completely from a lecture course to the case method. During a period of transition, difficulties are met with in that the students' study habits do not become well established. It is therefore of importance that cases be used under controlled conditions. That is to say, the preparation of case material should be facilitated by preparatory discussions or the assignment of specific reference readings. Furthermore, the use of preparatory questions should be instituted at the outset in order that thorough knowledge of the case details will be available at the time of class discussion.

Where cases are used thus intermittently it is also necessary that the conclusions be formally summarized after discussion so that the sense of completion is satisfied. Cases should be carefully selected for their pertinence to the topical sequence. Otherwise the student loses the sense of course unity essential to the maintenance of his interest.

The graduate student, expecting cases, is initially curious concerning their nature and his ability to deal with them. He discusses his experiences with others of his class and rapidly forms stereotypes of methods used by different teachers. He bases his satisfaction primarily upon the clarity with which his objective is outlined by the instructor. If he can understand clearly what is expected of him so that his time is not wasted in futile speculation, he is willing to work.

ECONOMICS IN ENGINEERING EDUCATION*

By WILLIAM D. ENNIS

Alexander Crombie Humphreys Professor of Economics of Engineering,
Stevens Institute of Technology

A. Delimitation, Relationships, Point of View

1. Subject covers more than traditional (formal) economics. It *includes* that subject, hence is broader than the "practical economics" (economics of engineering) of Fish, Grant, Eidmann.

   Economics in this sense is narrower, however, than *curricula* in Industrial Engineering, Engineering Administration, etc.

   It refers to a group of business subjects, more or less coördinated, given to C.E., M.E., E.E. and other divisions of students. At Stevens the coördination is complete: one department handles all subdivisions.

   (Debatable) Its field is the whole field of business, possibly excluding selling and advertising, credits and collections. It is not so much a *subject* as a *point of view.*

2. Should illustrative material be taken exclusively or mainly from the technical engineering field? Answer (*debatable*), No. Reasons:

   (*a*) The technical engineering departments should themselves conform with sound business principles in their treatments of problems.

   (*b*) Material from the general business field broadens the student, which is one important objective. The humanistic values are greater with the plan recommended.

   (*c*) The opposite procedure tends toward a degeneration into a technical review.

Students need expansion of sympathies and fluencies. Economics should be a cultural subject. "For some—not all—boys, quite irrespective of the question of how they are to earn their bread and butter, the engineering discipline is the better discipline

* A synopsis of two lectures delivered at the Economics Session of the Society's Summer School for Engineering Teachers, Stevens Institute of Technology, July 5–6, 1932.

toward culture." If we aim at a cultural discipline, we should aim consciously and deliberately at cultural values in economics.

3. Foundation subjects are (*a*) formal economics and (*b*) accounting—(*a*) the "science" (or philosophy) of business, (*b*) the "expression" (or language) of business.

B. Traditional Economics

4. Formal economics at Stevens is necessarily a sophomore subject. Two years' experimentation in teaching it inductively (through cases) gave fairly satisfactory results with the following topics:

   Characteristics of the American economic system
   Economic characteristics of manufacturing industries
   Industrial economics
   Business cycles, index numbers
   Elasticity of demand and supply, and their relation to price
   Marginal production and consumption
   Joint costs, class pricing
   Prices under competition and under monopoly
   American railways and their problems
   Governmental (municipal) borrowing

   The following topics were not treated at all during those years:

   Money and banking (see below)
   International trade
   Determination of distributive shares

For 1932–33 use was made of a new textbook in formal economics, experimentally. It turned out to be too long and too expensive for a 45-hour course. In 1933–34 we return to the inductive method, having added new case material on *Money and Banking* and on *Taxation*.

C. Dynamic Economics—Economic Objectives

5. Basic objective—a steadily advancing average standard of living

   Related considerations:

   (*a*) Cyclic fluctuations—can they be reduced?
   (*b*) Variations in individual wealth. *Can* they be reduced? How? *Should* they be reduced?

6. Various developments and proposals as related to the objectives:

   (*a*) *Savings* as the balance wheel. Need for better laws and better enforcement toward safeguarding investments, broadly and dependably.

(*b*) Artificial price-level stabilization. Effect on debtor-creditor relationships: various methods. Is stabilization compatible with the gold standard?

(*c*) The shorter working day and/or week. Increased leisure time a legitimate feature of an advancing standard of living. Need of balance.

(*d*) Adjustment of production to consumption. Excess facilities, conservation of natural resources, wasteful competition in distribution. Hindrance to progress in economic planning.

(*e*) Rational and irrational personal budgeting. Effects of high-pressure selling, competitive advertising and consumer credits on choice of satisfactions. Poor bargaining position of the consumer.

(*f*) Wider application of modern management standards. Productiveness not a matter of "sweating" the worker, but of wise planning.

(*g*) Governmental economy and rational taxation. Public works construction as a balance wheel: its limitations.

D. Accounting

1. Accounting, strictly defined, warrants less space than economics, broadly defined. Stevens subdivides it into *formal accounting* and *cost accounting.*

2. Formal accounting is taught from 11 "cases" (with some interlarded dogma) plus 4 prefatory pages and 7 closing pages looking forward to corporation accounting and finance (topic G): in all 60 pages, usually covered in 25 to 30 class hours.

3. The purpose is to develop a *point of view.* Hence stress is placed on journalizing. There is little drill. Students go through the operation of "closing" only once. Nothing more than incidental attention is paid here to questions of business policy.

4. Case 1 presents a Balance Sheet and shows the effect thereon of 10 different transactions.

5. Case 2, the one big case, deals with a lumber yard and covers these steps:

   a. One day's transactions are described and journalized by the student

   b. Summary records of remaining transactions during the month are similarly journalized

   c. Previous Balance Sheet and Ledger are presented. Student makes Journal adjustment entries and posts Journal to Ledger

d. Trial Balance is taken, operating accounts closed out and new Balance Sheet and Operating Statement prepared.

All of this has been done at page 22. Is this rushing things too much? Some say so.

6. Other cases provide constant review and deal with such subjects as:

Correction of errors
Application of orthodox forms to thumb-nail records
Opening a set of books (methods, not practice)
Deriving statements without closing books
Forecasted statements, giving effect to capital or operating readjustments
Surplus position vs. liquid position.

No expansion is contemplated. After four years' trial the foregoing program seems about adequate.

E. Cost Accounting

7. (*a*) In uniform product industries.
(*b*) Same, complicated by by-products. Costs of joint products (linseed oil and cake). Railroad costs.

8. Cost diagram for diverse product industries. Composite industries. Complete cost analysis for a steel foundry, illustrating uniform phase (to metal in the ladle) followed by diverse phase.

9. Overhead: two definitions: lists of overhead accounts. Examples of (diverse) apportionment in (*a*) garment manufacturing, (*b*) textile machinery manufacture. *Artificial example* of complete overhead distribution. "Standard basis" overhead, constant per time, not constant per unit produced (about the only emphasis on "standard costs").

10. Little stress is here placed on forms and records. There are many problems but little routine drill. Classifications and standard manuals are discussed and shown. The discussion terminates with a study of controversial matters like
(*a*) basis of charging out stores to process
(*b*) cost finding when prices cannot reflect costs
(*c*) constant and variable costs: the first of several illustrations of this important topic.

F. FINANCIAL MATHEMATICS

11. Formerly called "Invisible Costs"; amortization, depreciation, depletion.

Based on concepts of compound interest, annuities, present worth

Applications to installment selling, bond yields, bond redemption programs, insurance of various sorts, investments, perpetuities, capitalized cost, choice of equipments

Depreciation and depreciation accounting. Three types of life curves, with two of which the residual value is the difference between original value and the aggregate of depreciation charges. Is the purpose of depreciation to replace the *plant* or the *investment?* In the former event, depreciation charges must increase as prices rise, but accrued depreciation may be offset by the rising price level. Relation to valuation and rates: book value of plant not a determinator of rate base

This section is an informal introduction to an elective course in actuarial mathematics given by the department of mathematics.

G. FINANCIAL ORGANIZATION AND INVESTMENT

12. Based on 16 cases. Each is presented by complete financial statements as (elaborately) published. Over 100 pages. Cases vary. Kept current.

Purposes: Insight into 16 important industries including reorganizations and case histories

{ Comparisons of accounting methods and policies
{ Criticisms of standards of corporation publicity
{ Study of investment merit of securities

Cases prefixed by a little dogma (8 pages) on such topics as:

Purpose and advantages of corporate organization
Stock issues, capital liability
Bonds: types: arithmetic of convertible bonds
Rights, stock dividends
Margin trading and short selling
Super corporations, holding companies, interlocks

H. VALUATIONS: 32 PAGES

13. Background of constitutional law (8 pages, which might well be expanded). Includes valuations for rate making, taxation,

of mineral rights, insurance appraisals and the 80 per cent. clause.

I. Public Utility Rates: 100 Pages

14. History of railroad regulation. Principles of and formula for rate making. Court decisions on such topics as franchise value, going value, depreciation, historical and reproduction cost, franchise or contract rates, service charges, interstate commerce in utilities, the "used and useful" limitation. Criticism of current regulatory practice. Actual examples of rate structure from 9 kinds of public utility, followed by a summary of principles. The electric supply industry. Hydro-electric power. Example of complete report of gas and electric company in New York State to Public Service Commission. Disputed questions, such as:

    Submetering
    The New York City 5-cent Subway Fare
    Ontario Power

15. Freight Rates. An informational treatment, requiring constant revision.

16. Is too much attention devoted to Topics *H* and *I*?

    What engineers think
    What Nation's Business thinks ("The biggest problem ahead of American business")
    By-products of the study: mathematics vs. psychology in pricing

J. Elective and Graduate Courses

17. Courses both elective (Senior II) and Graduate:

    Advanced (formal) Economics
    Production Problems
    Business Problems (cases only)
    Economics of Inventions (cases only)

18. Courses for Graduates only:

    (1) Factory Management (an advance from Production Problems, above)
    (2) Advanced Accounting (cases)
    (3) Statistics (methods)

    The last should, in abridged form, be brought into the undergraduate program.

    The first is scheduled for important expansion, particularly with respect to what may be called the "philosophy" of wages.

K. Plans

Other contemplated expansions (for the undergraduate course) include

The terminology of formal economics (brief)

Forms of economic organization (individualism vs. socialism)

It is hoped within the next two years to develop some data regarding the world's natural resources: a sort of highly quantitative and detailed commercial geography.

STUDY OF GRADES AND GRADING PRACTICES AT NORTHEASTERN UNIVERSITY

By WILLIAM C. WHITE

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Although many studies of grades and grading systems have appeared in educational journals in the course of the last few years, most of these articles have been concerned primarily with grade distributions in non-technical schools. It may be, therefore, that a study based upon data in professional schools will be of interest to engineering educators. After rather wide correspondence with administrative officers of engineering schools, the writer has the impression that engineering teachers generally look upon grade studies made in colleges of liberal arts as having little value as guides for marking in technical courses.

Accordingly this paper has been prepared, primarily to record the results of a careful study of grades and grading practices in the Schools of Engineering and Business Administration of Northeastern University. The study confined itself to a consideration of the more general aspects of grades and methods of grading. It did not include a discussion of problems peculiar to certain departments, such as the problem of grading in ability groups, specialized grading, relative weights to be given to home work, class work, quizzes, etc., in compiling grades, and similar considerations. On the other hand the study did endeavor to ascertain what general elements entered in to the compilation of grades throughout all courses, what the purpose of grades was conceived to be, and what distributions of grades were resulting from current practice.

In 1927 the faculty of the Schools of Engineering and Business Administration of Northeastern University voted to replace the numerical system of grading then in use, based on a 100 point scale, by a letter grading plan comprising only five grade intervals. Substantial evidence seemed to indicate that from five to seven marks were all that could be used effectively by college teachers and the trend among American institutions favored the five point grading scale.

At the time of its adoption the grading system at Northeastern was intended to be an absolute scale; *i.e.*, each mark was to indicate a certain definite level of accomplishment irrespective of the grade distributions that might result. The grades were described as follows:

Grade "A" .....excellent attainment
Grade "B" .....above average attainment
Grade "C" .....average attainment
Grade "D" .....lowest passing grade
Grades "F" & "FF" .....failure—"F" permits condition examination; "FF" does not.

It was tacitly assumed that these grades would be interpreted with reasonable uniformity by the seventy-two members of the faculty and that, consequently, the system would be sound and equitable.

In order to ascertain whether the plan was actually working in accord with expectations, the administration last year conducted a survey of the results obtained during the two year period from 1928 to 1930. Two avenues of approach were made available for this survey: (1) the statements of faculty members regarding their methods of grading and (2) a statistical study of the total final grades given in the Day Division during the school years 1928–29, 1929–30.

Statements of Faculty Members in Regard to Grading

For the purpose of tabulating grading procedures in convenient form a questionnaire was prepared and submitted to all teaching members of the faculty. The information obtained in this way was clarified and supplemented wherever necessary by means of personal interviews. All of the material was then carefully summarized. The results indicate that the faculty were attacking the problem of grading from a wide range of viewpoints. Specifically:

A. Bases of Grading

The bases of grading in use by the seventy-two members of the Day Division Faculty are tabulated in the following chart:

Factor	Percentage of Faculty Members Who Stated that Each Item Entered Directly into the Compilation of Their Grades as Being of		
	Paramount Importance	Some Importance	No Importance
Actual achievement in the course	100	0	0
Discipline	2	6	92
Status of student in other courses	0	4	96
Effort put forth	6	80	14
Participation in student activities	0	10	90
Attitude in class	4	44	52
General intelligence	8	28	64
Personality and general character	0	20	80

A study of these tabulations indicates that while there was unanimity in considering achievement in the subject matter of the course as of primary importance in compiling grades, yet all of the other factors listed also directly affected the grading of from four to eighty per cent of the instructors. It is obvious that there was no clear-cut uniformity in bases of grading other than a general acknowledgment that actual achievement in the course should be *one* factor of primary importance in arriving at marks.

B. Distribution of Grades

a. Two-thirds of the faculty stated that they graded wholly according to fixed standards of achievement; that is, they had in mind certain definite levels of accomplishment for grades A, B, C, D, F and FF that they used in assigning marks regardless of the resulting distribution of grades.

b. Eight teachers graded wholly or partially on the basis of the achievement of the student in proportion to his apparent ability.

c. Four instructors graded wholly on the basis of relative achievement, and planned to assign a certain percentage of A's, B's, C's, etc., regardless of the students' absolute accomplishments.

d. The remaining teachers used a combination of the three practices already mentioned.

e. A number of instructors stated that they distributed grades on several different bases, depending upon the nature of the course and the year in which it was given. The following quotations from questionnaires submitted by the faculty indicate various types of grading procedure then in use:

"I grade according to fixed standards in junior and senior courses. In sophomore courses I grade according to relative achievement."

"My method of grading varies with different courses. I have three different bases upon which grades are compiled depending upon the nature of the course and the year in which it is given."

"I grade wholly according to fixed standards for grades A, B, C, and FF. For the grades D and F I try to look ahead to the needs of future courses. If the student in my opinion knows enough to go on with advanced work in his curriculum I give him D; if he does not know enough to go on, I give him F."

Study of Total Final Grades

In table I are shown the percentage distributions of all final grades given by instructors, and in table II the distribution by de-

TABLE I

PERCENTAGE DISTRIBUTION OF ALL GRADES GIVEN BY INSTRUCTORS IN THE DAY DIVISION OF NORTHEASTERN UNIVERSITY DURING THE SCHOOL YEARS 1928–1929 AND 1929–1930.

(Instructors with Fewer Than 200 Grades Not Included)

Instructor Number	Percentage of Total Grades Issued Which Were				
	A	B	C	D	F & FF
1	14	25	27	23	11
2	2	15	48	34	1
3	4	22	43	28	3
4	9	18	23	33	17
5	4	20	49	22	5
6	8	29	34	20	9
7	3	16	33	34	14
8	10	20	34	24	12
9	5	20	23	28	24
10	6	18	35	27	14
11	4	41	22	25	8
12	1	11	43	29	16
13	3	16	38	34	9
14	4	14	40	23	19
15	1	29	49	20	1
16	5	34	40	19	2
17	9	24	27	25	15
18	4	27	35	27	7
19	4	23	40	22	11
20	5	19	39	31	6
21	5	29	39	20	7
22	5	17	40	28	10
23	5	28	43	16	8
24	3	22	44	28	3
25	10	22	25	28	15
26	8	17	46	21	8
27	3	23	50	19	5
28	4	30	39	19	8
29	6	30	34	16	14
30	2	17	43	28	10
31	6	14	35	34	11
32	5	21	36	27	11
33	7	21	35	26	11
34	6	22	52	18	2
35	5	23	39	25	8
36	5	17	30	31	17
37	8	18	26	32	16
38	4	28	48	16	4
39	10	18	27	35	10
40	5	26	33	26	10
41	8	20	31	28	13
42	0	19	52	29	0
43	8	18	26	32	16
44	5	23	44	24	4
Average	5	22	37	26	10

TABLE II

PERCENTAGE DISTRIBUTION OF GRADES, BY DEPARTMENTS IN NORTHEASTERN UNIVERSITY DAY DIVISION DURING THE SCHOOL YEARS 1928–1929 AND 1929–1930.

(Unclassified Courses Not Included)

Departments	Per cent of Total Grades Issued Which Were				
	A	B	C	D	F & FF
Number 1	4	21	41	27	7
Number 2	2	16	43	26	13
Number 3	3	19	40	27	11
Number 4	8	22	35	25	10
Number 5	1	38	43	18	0
Number 6	3	26	42	24	5
Number 7	10	22	26	26	16
Number 8	4	17	36	31	12
Number 9	8	19	26	28	19
Number 10	5	16	40	30	9
Number 11	6	17	31	30	16
Average	5	21	37	26	11

partments in the Day Division of Northeastern University during the school years 1928–29 and 1929–30. Of striking significance in both tabulations are the extremely wide variations in the proportions of grades assigned. For instance, instructor number 42 gave no A's and no F's while number one gave 14 per cent A's and 11 per cent F's. Instructor number nine consistently failed 24 per cent of his classes while instructor number 20 who was in the same department and teaching the same type of work to the same students failed only 6 per cent. When it is realized that these tabulations represent all final marks given over a two-year period the lack of uniformity in the grade distributions becomes rather startling. The range in percentages of the several final grades issued by the forty-four instructors * recorded is as follows:

A's ranged from 0 to 14 per cent
B's ranged from 11 to 41 per cent
C's ranged from 22 to 52 per cent
D's ranged from 16 to 35 per cent
F's ranged from 0 to 24 per cent

* Instructors who had turned in fewer than 200 marks over the two year period are not included.

Similar variations in grade distributions appear in the tabulation of departmental averages, although the discrepancies are slightly smaller than those for individual instructors. In this case

A's ranged from 1 to 10 per cent
B's ranged from 16 to 38 per cent
C's ranged from 26 to 43 per cent
D's ranged from 18 to 30 per cent
F's ranged from 0 to 19 per cent

Furthermore, it would seem that this is not a situation in which only a few isolated cases deviate radically from the norm, but rather a situation in which there is considerable lack of common understanding as to the meanings of the several grades employed. One hesitates to believe that achievements in various subject matters could actually have been distributed in accord with the marks that were assigned.

It seems fair to conclude that the principal defect in the grading plan is the inadequacy of the definitions provided for the five grade intervals. At the same time it is not an easy task so to define a grade as to insure a common understanding of its meaning by all the members of a large faculty. No amount of description alone is likely to result in exact and readily understandable definitions of grades.

For this reason many institutions have defined their grading systems, wholly or partially, in terms of the relative achievements of large representative groups of students rather than in terms of any absolute scale. Such grading plans are based upon the theory:[1]

1. "That the performance of a representative group sets the most logical standard of scholastic achievement,
2. "That any individual's mark should properly represent his relative achievement within such a group, and
3. "That equal relative achievement as thus judged, should receive equal credit, whether in the same or different subjects of study."

In other words, the distribution of marks on a relative plan[2] "is based upon the assumption that approximately the same distribution of grades should be made in any course taken by the same group of students; and that the grades distributed to different groups of students in the same or in different courses, should vary not according to the profundity of the materials studied, nor according to the severity or leniency of different instructors, but according to the ability of the students in the different groups."

Admittedly,[2] "measurement by such a standard will fail to signify several important elements of achievement. It will not allow for differences in the quality of instruction, nor for differences

arising from the greater inspiration students receive from some instructors than from others, nor for the greater achievement due to unusually hard work under an instructor with great driving power. It will not reflect that greater achievement a student attains because the school is a better school, because of improved teaching methods and technique, because of the more careful selection of materials for study, because of a better organized curriculum. *But no means are known for measuring these things.* Certainly they are not measured by the unstandardized grading now generally employed."

Certain advantages gained by adopting some standard distribution as a guide are clearly set forth by Douglass:[3]

1. "It tends to prevent bad feeling between teachers who cannot understand the standards of each other, and who are likely to imply bad motives.
2. "It tends to prevent the confusion of parent and pupil, who are alike inclined to feel that an A is an A, no matter who gives it.
3. "It gives the marks some objective significance for purposes of school records, and the marks of different teachers may be compared in a quantitative way for purposes of measurement in experiments and investigations."

Several objections to the plan have been raised by its opponents. For example,[4] "it might be argued that grades should be expected to average higher in some departments than in others. Data available from several institutions indicate that such is not the case. Mathematics ranks highest in one institution and lowest in another with respect to the percentage of A grades given. Education ranks highest in one institution and lowest in another in the percentage of A grades given. In one institution Freshman English has the highest percentage of failures of all subjects taught; in another institution there are practically no failures in Freshman English, although 25 per cent of the students fail in Freshman Mathematics. No correspondence appears in the institutions studied between the type of subject and the percentage of high or low grades awarded."

Again, engineering teachers are prone to believe that they are perfectly capable of grading with exactness according to absolute standards. Assuming the desirability of grading in this manner, it has been found quite impossible up to the present time to establish such standards. Countless experiments have demonstrated beyond any doubt that instructors' judgments as to standards of achievement are neither uniform nor dependable. Grading on such an arbitrary basis is extremely unreliable and unfair—to say the least. Not only has it been demonstrated that in any subject a

given piece of work will receive widely varying grades from different instructors but also it has been shown that the same piece of work will be marked quite differently by a single instructor at different times. Other objections that have been raised against the use of a standard curve as a basis for defining grades are briefly discussed in the following paragraphs.

The use of a standard curve as a basis for distributing marks results in unfairness to the members of small classes. This objection grows out of a complete misunderstanding of the theory underlying the use of such a curve. Enlightened authorities do not contend that tabular distributions should be blindly imposed upon small groups. It is not expected that instructors will turn in for every class the exact number of A's, B's, C's, etc., incident to a normal distribution, but only that the distribution of all marks turned in by an instructor over a period of two or three years will agree very closely with expected frequencies.

Prescribed use of a standard curve is unfair to instructors in that it infringes upon academic freedom. This is distinctly untrue, unless one insists upon interpreting academic freedom as unlimited license to indulge one's personal whims in the marking of students. The use of a standard curve imposes no limitations concerning what shall be taught or how it shall be taught. Furthermore, it leaves the instructor entirely free to rank his classes in the order he deems appropriate in the light of his knowledge of their relative achievements. What the requirement of the standard curve does, in effect, is to substitute a fairly reliable scale for the measurement of scholastic achievement in place of the well intentioned but demonstrably unreliable guesses of the teaching staff. Use of the curve tends to equalize the values of marks given by various instructors, but it militates against academic freedom no more than does any other administrative regulation, such, for instance, as one stipulating that the grade L shall be used for all cases in which a failure is removed by condition examination.

The prescribed use of a standard curve by limiting the permissible percentage of failures tends to lower the standards of the school. It would seem that the standards of a school should be established essentially by the group of students it admits and not by arbitrary fiat. The subject matter and instructional methods employed should be adapted to the needs of the students concerned. A high percentage of failures does not necessarily imply high standards; it may as well result from poor teaching or from inaccurate tests and measures of student achievement.

Many institutions have adopted grading systems based directly upon the curve of normal probability. Since the beginning of the century some fifteen or twenty such tabular distributions have been

proposed by various educational authorities. Among the most recent is that suggested by Eells [6] who distributes grades in a five point system as follows: 6 per cent A, 22 per cent B, 44 per cent C, 22 per cent D, 6 per cent E.

Other colleges have established their own curves empirically on the basis of actual experience with large numbers of grades. The particular standard distribution adopted does not seem to be of as much importance as the fact that *some* guide be established which will tend to equate the marks of different instructors. As one educator has said: "At the present stage of our educational measurements any grading system can hardly be more than a gentleman's agreement to play the game according to the rules."

The actual distribution of all final grades given in Northeastern University Day Division at the close of the school year 1929–30 was: 6 per cent A, 22 per cent B, 38 per cent C, 25 per cent D, and 9 per cent F. A comparison of this distribution with that based upon the probability curve and proposed by Eells is shown in Fig. 1.

In the light of these considerations the faculty voted to adopt as a guide for the distribution of grades in all departments the empirical curve developed at Northeastern and to establish the following principles of grading for all courses offered in the Day Division:

1. Purpose of grades: The essential purpose of marks is to differentiate accurately and appropriately among the students to whom the grading scale is applied.
2. Basis of grading: All grades are meant to indicate *achievement in the subject matter of the course* in which they are given and nothing more or less than this.
3. Distribution of grades: All grades are based upon the achievements of large representative groups of students and not upon the relative achievements of the individuals in any single class. In the long run, grade distributions in all courses should approximate the empirical standard established by common agreement.

The net effect of the new scheme of grading is merely to place the grades of all instructors in all courses on the same basis. It does not raise or lower the general level of accomplishment at present required in the Day Division, and it does not limit the distribution of grades in any single class in any way. The percentage of eliminations for poor scholarship will remain essentially the same as heretofore; so, also, will the ratio of entering freshmen to graduating seniors. A more uniform, and hence a more equitable, distribution of passing grades is the chief advantage of the new system. It should result in greater fairness to students and in a clearer

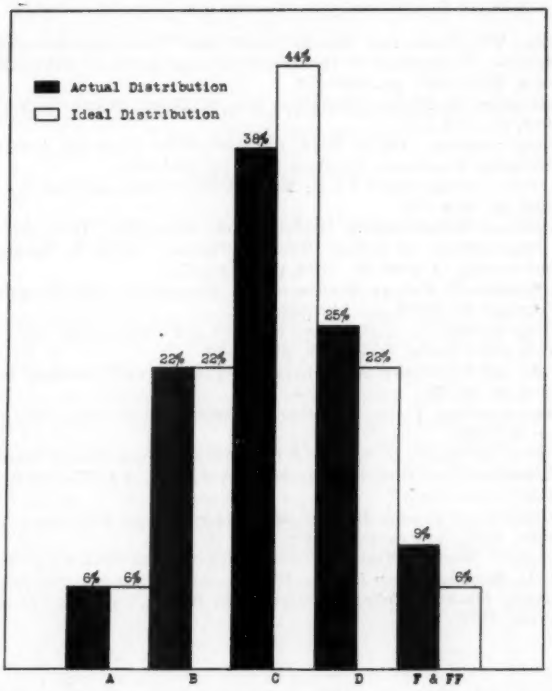

FIG. 1. Actual distribution of 11,397 final grades given in Northeastern University Day Division in 1929–30, compared with Eell's theoretical distribution.

understanding on the part of instructors, students, and parents as to the meaning of each mark in the grading scale.

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REPETITION EFFECT IN IOWA MATHEMATICS TRAINING EXAMINATIONS

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In the spring of 1932, The Iowa Mathematics Training Examination was given to certain seniors in the high schools of Minnesota who chose to take it in connection with a required series of tests comprising a College Ability Test. Of these students, 83 entered the College of Engineering and Architecture at the University of Minnesota in the fall of 1932 and were given the same identical examination during Freshman Week just before college opened.

An investigation has been made to determine the repetition effect, if any, upon the scores of this group. The lower quartile, the median, and the upper quartile raw scores of the entire group for the two examinations are shown in the following table.

	Percentiles of Raw Scores		
	25th	50th	75th
March, 1932 in high school.....	39.4	44.1	49.5
Sept., 1932 at U. of Minn.....	44.7	52.1	58.7

It will be noticed that a substantial increase in the raw scores is shown for the percentiles given and that this increase is greater for the higher percentiles.

The individual scores, reduced to percentiles based on Iowa norms and grouped according to high schools are shown in the following list. The College Ability Test percentiles are added for information or comparison.

The differences varied from $+79$ to -30, plus meaning that the second score was the higher.

It is very probable that the increases in scores are not due entirely to repetition of the examination, for undoubtedly some of the students were taking mathematics in high school following the first test and consequently had had more training when they made the second attempt.

Student	High School	C.A.T. %ile	Iowa Mathematics Training Examination %ile		
			In H. S. March, 1932	At University Sept., 1932	Difference
			Minneapolis High Schools		
4	B	43	97	97	0
5	B	3	43	85	+42
6	B	72	94	96	+ 2
7	B	29	24	85	+61
16	E	10	83	97	+14
17	E	86	65	85	+20
23	G	90	83	85	+ 2
24	G	34	77	93	+16
25	G	29	98	99	+ 1
26	G	30	12	46	+34
27	G	40	87	98	+11
28	G	7	94	98	+ 4
29	G	24	65	81	+16
30	G	5	79	87	+ 8
31	G	2	15	34	+19
32	H	21	75	98	+23
33	H	49	79	79	0
34	H	19	75	85	+10
35	H	39	81	97	+16
36	I	27	72	75	+ 3
37	I	20	65	93	+28
38	I	42	65	77	+12
39	I	40	75	91	+16
40	I	54	76	94	+18
41	I	61	96	98	+ 2
42	I	8	85	91	+ 6
43	J	34	75	60	−15
44	J	81	49	83	+34
45	J	53	91	98	+ 7
46	J	48	77	89	+12
47	K	52	93	100	+ 7
48	K	87	94	91	− 3
49	K	81	81	95	+14
50	K	34	83	90	+ 7
51	K	45	63	85	+22
52	K	20	92	100	+ 8
53	K	53	96	98	+ 2
54	L	23	65	83	+18
55	L	89	89	96	+ 7
56	L	56	81	98	+17
57	L	48	85	55	−30
58	L	68	75	93	+18
59	L	63	49	52	+ 3
60	L	29	52	72	+20
61	L	48	70	79	+ 9
82	P	93	68	68	0
83	P	80	29	22	− 7

Student	High School	C.A.T. %ile	Iowa Mathematics Training Examination %ile		
			In H. S. March, 1932	At University Sept., 1932	Difference
St. Paul High Schools					
1	A	11	12	91	+79
2	A	77	89	98	+ 9
3	A	40	93	99	+ 6
8	C1	83	40	77	+37
9	C2	7	51	46	− 5
10	C3	12	52	77	+25
75	C4	75	85	65	−20
11	D	79	81	96	+15
12	D	1	60	96	+36
13	D	93	83	100	+17
14	D	80	68	65	− 3
15	D	49	72	96	+24
18	F	5	72	89	+17
19	F	56	89	96	+ 7
20	F	28	77	87	+10
21	F	8	65	93	+28
22	F	5	92	100	+ 8
62	M	53	83	95	+12
63	M	49	90	93	+ 3
79	O	23	49	52	+ 3
80	O	30	70	77	+ 7
81	O	77	57	63	+ 6

Student	High School	C.A.T. %ile	Iowa Mathematics Training Examination %ile		
			In H. S. March, 1932	At University Sept., 1932	Difference
High Schools Outside Twin Cities					
64	N1	5	46	57	+11
65	N2	40	22	32	+10
66	N3	80	91	98	+ 7
67	N4	16	85	91	+ 6
68	N5	80	96	94	− 2
69	N5	14	90	92	+ 2
70	N6	37	72	72	0
71	N7	21	75	85	+10
72	N8	25	63	79	+16
73	N9	62	68	77	+ 9
74	N10	69	65	89	+24
76	N11	73	94	98	+ 4
77	N12	28	70	65	− 5
78	N13	81	79	96	+17

AN EXPERIMENTAL COURSE IN MECHANICS OF MATERIALS*

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Introduction

The principal purpose of the experimental course in the mechanics of materials at the University of Michigan has been to acquaint the students with the properties of materials and to afford them a chance to verify the formulas discussed in the theoretical course in Strength of Materials. The plan has been, furthermore, to make the student familiar with the physical side of the subject by discussing studies of single crystals, the structure of metals, photoelasticity and the use of recent methods and instruments in research. It has not been the intent to teach students the process of testing materials. The testing of concrete is done separately under the Department of Civil Engineering whose laboratory handles all the state highway work and is required of students specializing in that division.

In agreement with these principles the course described here has been developed. The program is divided into two parts, (1) lectures and demonstrations, and (2) experiments performed by each individual student.

Distribution of Time

The course in mechanical properties of materials provides one hour of credit. The distribution of time in the semester is practically evenly divided between the lectures and demonstrations and the individual experiments, being seven weeks and eight weeks respectively. A semester of sixteen weeks, therefore, permits either time during the extra week for organization and arranging suitable hours for meeting or review and an opportunity for completing unfinished work. A maximum of two and one-half hours per week is required of the student. During the weeks when lectures and demonstrations are given, two single-hour periods on separate days are observed, whereas when the student is accomplishing experiments a period each week of two and one-half consecutive hours is spent.

* Presented at the 40th Annual Meeting, S. P. E. E., Corvallis, Oregon, June 29–July 1, 1932.

In so far as possible this experimental course is designed to parallel and thereby be complementary to the theoretical course in the Strength of Materials. The order of presenting the material, then, is patterned after the analytical course. The present course is opened with introductory lectures during two weeks on tension and compression with special emphasis on the physical behavior. Strain hardening, residual stresses, structure of metals, and single crystals are given attention.

Directly following these lectures, the student spends four weeks accomplishing as many experiments—two on tension and two on compression. Each of the twelve sections of from twelve to sixteen students is divided into four smaller groups of three or four men. Each group performs all of the experiments during the four weeks and, inasmuch as the four groups are operating simultaneously, the order of the experiments is different for each group.

In the following three weeks are given lectures in time effect, elastic hysteresis, stress concentration, fatigue of metals, metals at high temperatures and photoelasticity. This seeming interruption in the logical schedule of experiments is designed to permit the student an opportunity to learn the theory of torsion and bending which is being presented in the course in Strength of Materials in parallel with this experimental program.

The remaining set of four experiments requires one week for the study of torsion and three weeks of bending of beams. The manner of conducting this portion of the work is similar to that for the first set of experiments.

The final two weeks are spent in lectures and demonstrations on various strength theories, working stresses and buckling of columns.

The program of the course during the semester is given in the accompanying table. In the case of the work in the laboratory, it is understood the order that the various groups observe in performing the experiments may be different than that listed.

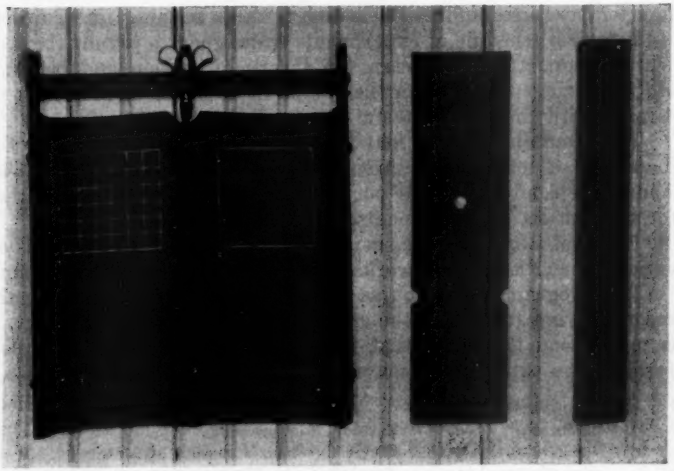
Week	*Division*	*Subject Matter*
1	Lecture	Tension, Compression
2	Lecture	Single Crystals, Structure of Metals
3	Experiment I	Tension Test—Elastic Range
4	Experiment II	Tension Test—Plastic Range
5	Experiment III	Compression Test—Elastic Range
6	Experiment IV	Compression Test—Fracture
7	Lecture	Time Effect, Elastic Hysteresis, Stress Concentration
8	Lecture and Demonstration	Fatigue of Metals
9	Lecture and Demonstration	Metals at High Temperatures, Photoelasticity
10	Experiment V	Torsion Test—Shaft—Helical Spring
11	Experiment VI	Flexure of Beams—Stresses

12	Experiment VII	Deflection of Beams—Cantilever—Simply Supported Beam
13	Experiment VIII	Deflection of Beams—Statically Indeterminate Problem—Beam on Three Supports
14	Lecture	Various Strength Theories
15	Lecture and Demonstration	Working Stresses, Buckling of Columns
16	Extra Periods	Review and Examination

Lectures and Demonstrations

The portion of the work embracing the lectures and demonstrations includes a treatment of the subjects mentioned above.*

The lectures are generously illustrated by lantern slides. Mechanical models and test specimens are frequently used to clarify and augment the explanations. As examples, Lueders lines on polished steel surfaces give visual evidence of sliding during plastic deformation, the Jenkins model † serves to show the effect of hys-



a *b* *c*

Fig. 1. Rubber Models. *a*. Pure Shear. *b*. Stress Concentration. *c*. Bending of a Beam.

teresis in metals, and rubber models are convenient in showing stress concentration at holes, fillets and re-entrant corners. In Figure 1 is pictured several rubber models illustrating: (*a*) pure

* S. Timoshenko, "Strength of Materials," Part II, Chapters V, VI, VII. Much of the subject matter presented in the lectures and demonstrations is discussed in this book.

† Jenkins, C. F., *Engineering*, Vol. 114, 1922, p. 603.

shear, (*b*) stress concentration at a central hole and at notches, and (*c*) bending of a beam.

Although lectures and demonstrations are essentially integral, it is generally believed good practice to present the theory of the subject and then show the apparatus and experiment. Fatigue of metals under variable stresses is felt to be of considerable importance. The student is given a fundamental knowledge of fatigue phenomena, methods of making endurance tests, examples of failures produced in these tests and also in practice and is shown various fatigue apparatus in the laboratory. The importance of reducing stress concentration to a minimum is emphasized.

Due to the great practical importance of materials to withstand high temperatures, the student is told of the properties of metals at elevated temperatures when subjected to short time static tests and to long time creep tests. Typical curves of the mechanical properties at various temperatures are shown. The different test methods of determining creep data by the tension and by the torsion apparatus are seen and explained in the laboratory.

Photoelasticity has demonstrated its usefulness in the industrial laboratories as well as in the research laboratories of universities. This method of stress analysis is directly capable of indicating regions of high stress concentration in machine parts. The elementary theory is given the student, the possibilities of the method, photographs from previous research work are seen, the laboratory apparatus is shown and simple transparent models are used to give actual results.

A study is made of columns having various constraints of the ends. The two simple cases investigated include a column with hinged ends, Figure 2, and one with a clamped and a hinged end. Euler's formula, $P_{cr} = \pi^2 EI/l^2$, which has previously been developed in the theoretical course in Strength of Materials is employed to calculate the critical load in each instance. The value of EI for use in Euler's formula has been determined for the cases at hand by considering each system as a beam, applying lateral loads and measuring the resulting deflection. The columns are each axially loaded in turn, noting the lateral deflection, until large displacements occur. The load at this point is then compared with the critical value obtained by the analytical method. Particularly because good agreement is found between the two methods, the student develops considerable confidence in the formula for the case of slender bars.

Throughout the course only two series of lectures and demonstrations are given into which the students of all sections are divided. Complete notes are taken by each student on each chapter

of the work including the sketches of demonstration apparatus, data and results of the experiment. Representative questions covering each phase of this part of the course are answered in writing, following each set of notes.

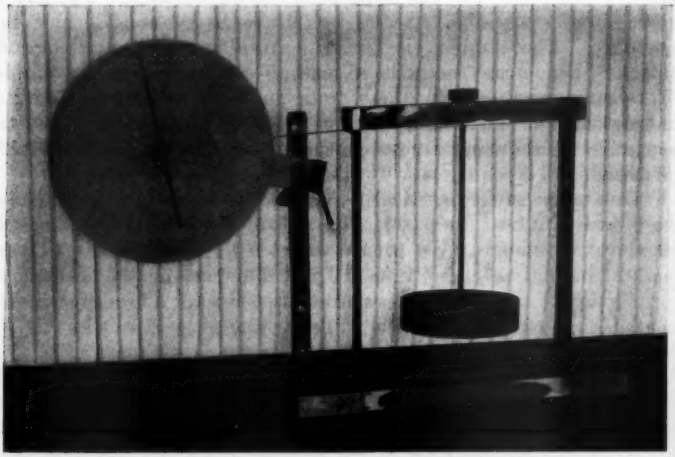


FIG. 2. Demonstration Model Illustrating the Buckling of Slender Column. (Model equivalent to a column with free ends.)

LABORATORY MANUAL

A laboratory manual has been specially developed for this course. The aim has been to provide the student with an opportunity to keep in a bound form his notes, sketches, data, answers to questions resulting from the lectures and demonstrations, in addition to a guide to the individual experiments performed by the student, the data, curve sheets, computations, results and answers pertaining thereto. To this end, the manual has been prepared. For the lectures and demonstrations sufficient blank pages and question sheets are provided. For the experiments directions are outlined for the student describing the problem to be undertaken, the material and equipment to be used and the method of procedure to be followed. The data sheets and co-ordinate paper are included. Each experiment is concluded with a set of typical questions to which written answers are expected.

EXPERIMENTS

As was mentioned, the value of the course is believed to lie in furnishing the student with a physical picture of the behavior

of materials under stress and to give him confidence in the formulas derived in Strength of Materials. The experiments have been designed with this object in mind. We believe that too much value is generally placed on laboratory technique and the mechanics of report writing. It has been the intent in this course to reduce the time and effort in this direction in so far as possible.

The experiments are set up ready for test when the student enters the laboratory. It is appreciated that the student gains valuable experience by assembling the apparatus for the experiment. It has been felt, however, that the greater amount of material which can be covered in the limited time by previously having the experiments ready for the student is of real importance. Rather, then, than to reduce the amount of material the present scheme has been resorted to. His preliminary task is to inspect the set up, investigate how the information is to be obtained in the light of his previous study of the directions in the manual. Initial readings and essential measurements of the system are recorded in the proper places in the manual.

Competent laboratory assistance is available then for the purpose of either operating the machine during the test or instructing the group of students in the manipulation of the apparatus in the event of ready understanding. The data from the experiment is entered in the forms provided in the manual, the necessary computations made, the required curves plotted and answers to the questions written all within the two-hour period. The instructor in charge circulates from one group to another throughout the performance of the experiments in order, by means of questions, to bring out student discussion and salient points of the experiment. At the close of the period each student has a complete and orderly record of the work in his manual which he submits to the instructor for additional comments. The manual is made available to the student the following day. Prior to the next laboratory period, the student may study from his manual the experiment which he will be expected to accomplish.

Experiment I

The first experiment is the tension test of a ductile material within the elastic range in which the modulus of elasticity and elastic hysteresis are studied. A specially constructed tensile machine of 10,000 pounds capacity for hard operation is used. Marten's mirror instruments of 200 mm. gage length indicate deformations of the two specimens in turn; one of mild carbon steel .375 inches in diameter, and the other of cold drawn brass .3125 inches in diameter. The student investigates in a suitable source the ap-

proximate values of the proportional limit, decides upon safe total loads to impose upon the specimens in order that they remain well within the elastic range. Two series of loadings and unloadings are made on each specimen, taking data of load and deformation which are subsequently converted into stress and strain. The stress-strain curves are plotted and the modulus of elasticity calculated from these curves. The hysteresis loops are noted, observing that hysteresis differs between various materials.

Experiment II

In the second experiment the tension test of ductile material is studied over the plastic range. The proportional limit, yield point, ultimate strength, elongation and reduction of area are investigated. The tests are made in an Olsen lever machine of 100,000 pounds capacity. The several specimens include two standard design tensile test bars, one of annealed mild carbon steel and the other of annealed copper. Each bar has been marked at one-quarter inch intervals. A specimen of annealed mild carbon steel is provided having all dimensions similar to a standard test bar except that the reduced section is one-sixteenth inch long for the purpose of studying the effect of inhibiting free sliding or "necking." In addition to these specimens of ductile material, a tensile test piece of cast iron is included, chiefly for comparative purposes.

To each of the standard test specimens in order is attached an Olsen Lewis-Hayes automatic strain gage with a sensitivity of 1/100,000 inch. A Michigan * dial is employed to indicate the displacement of the movable head. The tensile load on the specimen is raised until marked yielding is observed on the gage; taking simultaneous data of load and elongation, together with the dial readings. The sensitive instrument is then removed and data of the load and the movement of the head are recorded up to fracture of the specimens. Curves are plotted showing stress-strain relations during the period while the sensitive strain gage is attached and also total load against total movement of the head. From the first sets of curves, proportional limit and yield point in the case of the annealed mild steel only, are determined. From the latter set, the ultimate strength and the breaking strength are found. The ductility is studied by a measurement of the intervals between the original one-quarter inch marks. It is appreciated by the

* This instrument for measuring linear displacements was made in the shops and consists of a small drum mounted on an axis to which is attached a pointer which moves over a graduated scale. The drum is rotated by a fine thread connected to the object whose displacement is under investigation. The dials are capable of indicating a movement of 1/1000 inch. The dial is seen in Figure 2.

student that a standard gage length must be observed in reporting percentage elongation. This length, according to the adopted rule, $l = 4.5\sqrt{A}$, is two inches and percentage elongation is calculated on this basis. The reduction of area is determined by comparing the area at the reduced portion with the original area in the usual manner. The types of fractures are examined for the cases of these ductile materials.

The fracture of ductile materials in tension when necking is permitted shows two regions; the outer one which is the result of free sliding with surfaces more or less at 45° with the axis of the specimen and an inner portion at right angles with the axis, having a crystalline appearance commonly associated with a brittle fracture. The student learns that the failure of ductile materials is by sliding due to shearing stresses and, under the action of shearing stresses alone, fractures exhibited by the outer section are expected. The complication in the stress condition at the necked section requires another explanation for the central portion. Instead of only axial forces there are component radial stresses resulting from the inclined surfaces. An element at the center, then, is subjected to a three-dimensional stress which, as is well known, produces a fracture resembling that of brittle material.

The effect of grooves is investigated by use of the annealed mild steel specimen with the very short reduced section. Here the possibility of necking freely is eliminated. Practically no sliding will result so that the specimen fails due to tension which produces the "brittle" fracture. Due also to the maintenance approximately of the original cross sectional area, the ultimate strength will be greater than in the case of the standard form of specimen.

In the case of the cast iron test piece, fracture is of the brittle type due to tensile stresses or separation and ductility is absent. This compares favorably with the situation found in the specimen of ductile material having the narrow groove.

Experiment III

The compression test of a brittle material in the initial stage of loading is made to determine the modulus of elasticity and Poisson's ratio. A Riehle lever machine capable of producing 200,000 pounds is employed. For this purpose a concrete block, 6″ × 6″ × 18″, is used to which are attached two Huggenberger Tensometers *

* Huggenberger Tensometers are strain-measuring instruments operating by two mechanical lever systems. The sensitivity is in the order of 1/120,000 of an inch. The sensitivity of the measurement of strain is increased in proportion to the gage length employed. The readiness with which these refined instruments can be attached and utilized in testing in the field as well as in the laboratory, makes them distinctly useful in many cases. The instruments are the manufacture of Dr. A. Huggenberger, Zürich.

for measuring the axial contraction over a 4 inch gage length and one similar instrument for measuring the lateral expansion over the thickness of the block. The setup is shown in Figure 3. Increments of load are applied and a record is taken of the Huggenberger readings corresponding to these compressive loads. On the

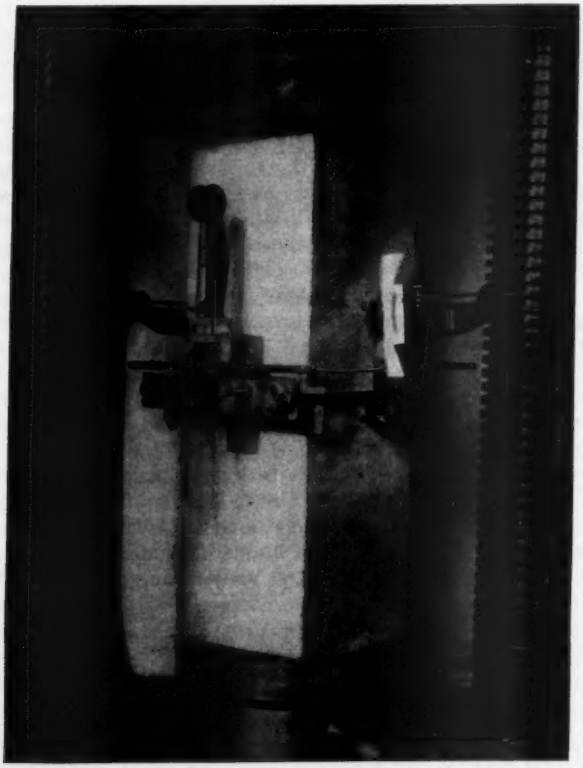


FIG. 3. Compression Test of Concrete to Investigate the Modulus of Elasticity and Poisson's Ratio by the Use of Huggenberger Tensometers.

curve sheets, against the axial stress is plotted the axial strain and also the lateral strain. From these a derived curve is obtained of axial against lateral strain by which Poisson's ratio is calculated. The modulus of elasticity of the concrete is found from the stress-strain curve. It is observed that for practical purposes the modulus of elasticity may be considered a constant.

Experiment IV

For the fourth experiment a compression test is made to fracture of a brittle material—concrete—and a non-isotropic material—wood. The test upon concrete is to illustrate the effect of the presence and the removal of end friction upon the ultimate strength and the type of fracture. In the tests of the wood samples, the modulus of elasticity, the ultimate strength and manner of failure are investigated when the load is applied at different directions with respect to the fibres. The effect of saturating wood with water is studied. In all of the cases, total load and total deflection readings are taken. The tests are made in a 50,000 pound Riehle lever machine.

For the test of concrete, three blocks are provided: two are 3″ cubes and one is 3″ × 3″ × 6″. One of the cubes has a coating of parafin on two opposite faces. The long specimen is placed on a self-centering plate in the compression machine, increments of load are imposed and the corresponding deflections recorded. The ultimate strength is observed.

The same procedure is followed in the case of the short specimen. The frictional forces caused by the pressure plates on the ends of the specimens produce, with the axially applied forces, resultant forces inclined toward the center of the specimen. The effect is to strengthen the end portion, causing conical formations to remain. The intermediate region expands resulting in splitting the material along vertical planes. When the specimen height is small, the cones merge or interlock so that the ultimate strength is higher than for the longer specimen.

The block having two opposite surfaces covered with thin layers of parafin is tested in the same manner. The frictional forces here are considerably reduced by the lubricating action of the parafin. In fact, as the parafin is pressed outward due to the pressure, there is even a slight outward force component encouraging spreading. The stress condition is essentially, however, one of axial forces. Splitting occurs on lines parallel to the axis as a result of Poisson's ratio effect, *i.e.* failure is due to separation. The ultimate strength is of the same order as that of the long specimen. Curves of total load and total deformation are plotted.

In testing wood, seasoned blocks of similar material are subjected to compression according to the same procedure outlined in the case of the specimens of concrete. One of two blocks, 1½″ × 1½″ × 6″, cut lengthwise of the fibres is soaked in water for several hours. The third block of the same dimensions is cut with the long axis perpendicular to the grain. A record of the load and deformation is made in each compressive test and the ultimate

strength noted. After plotting the data, the moduli of elasticity are determined and compared. The saturated specimen is observed to have much lower strength than the dry sample cut in a similar manner. The modulus of elasticity is also lower. The strength and modulus of elasticity of the specimen loaded across the grain are also less than the corresponding values of the dry block loaded parallel to the fibres. Failure of wood is by shearing the fibres and by crushing.

Experiment V

The fifth experiment is the torsion test in which are investigated the modulus of elasticity in shear, the helical spring and combined stresses. In the first part of the experiment a small circular rod of spring steel of 5/16″ diameter, clamped at one end and twisted at the other by small increments of torque, and a device for measuring the angle of twist, provides data from which the modulus of elasticity in shear may be calculated after the observed data has been plotted.

The next part concerns a helical spring constructed of the same sort of rod as was just investigated. After obtaining all the necessary dimensions and information of the spring system, and using the value of the modulus of elasticity in shear found above, the ratio of load to deflection is calculated for some given number of coils. The curve is plotted showing the relation between the load and the calculated deflection. The safe load that can be imposed on the helical spring is determined by use of the approximate formula developed in the Strength of Materials.

Experimentally, then, the relation between various loads and the corresponding deflection of the several coils is determined by adding rather large increments of weight to the helical spring and observing the resulting deflection of the coils by use of dividers and scale. The experimental results are plotted on the same curve sheet as just previously done, noting the agreement between the analytical and experimental methods.

The final part of the torsion experiment is a study of combined stresses by twisting a relatively large steel shaft of 2½″ diameter in an Olsen torsion machine of 200,000 inch-pounds capacity. Figure 4 is a photograph of the experiment. The safe maximum torque that can be applied is calculated from the formula. To the shaft is attached a Riehle goniometer for obtaining the shearing strain. It is known that directions at 45° with the axis of the shaft describe the lines of principal stresses, one in which there are tensile stresses and the other compressive stresses. Knowing the direction of the twist of the shaft, the student determines in which 45° direction tensile and in which compressive stresses operate. Two

Huggenberger Tensometers, each with a very short, ½ inch, gage length, are attached to the shaft so as to detect strain in each of the directions of principal stress. When such a short gage length as ½ inch is taken, it has been found that good agreement with the theory is found and it is not necessary to account for the curvature of the surface.

After the initial readings on the goniometer and the two Huggenberger Tensometers have been taken, several increments of torque are applied up to the allowable amount. The corresponding

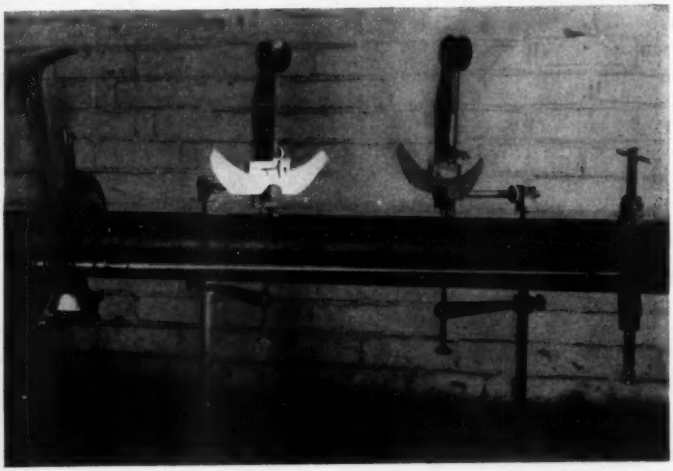


FIG. 4. Torsion of a Steel Shaft to Investigate the Modulus of Elasticity and Combined Stresses Using a Riehle Goniometer and Huggenberger Tensometers.

observations of strain are made. A curve is plotted of the values of the shearing stress and the shearing strain from which the modulus of elasticity in shear is calculated.

The relation between the principal stresses on the surface of the shaft and the maximum shearing stresses is found analytically. From the Huggenberger readings are determined the tensile and compressive strains. These strains are plotted against the corresponding principal stresses found above. From the plotted data, the values of the moduli of elasticity are calculated for the cases of tension and compression.

Experiment VI

This experiment in the flexure of beams is a study of stresses, curvature and the determination of Poisson's ratio. For the first part, a relatively large rectangular steel beam, $2'' \times 3'' \times 60''$ is put under pure bending in the 100,000 pound Riehle bending machine. The strain at various positions in the beam are measured by means of four Huggenberger instruments located as follows: at the outer fibres, intermediate fibres, neutral axis and laterally at the outer fibres.

The set up is studied and a sketch is made including the necessary dimensions, locations of the strain instruments and an indication of the forces acting on the system. The elastic line, shear and bending moment diagrams are drawn on which are indicated the proper values. The safe load that may be imposed upon the beam by the machine is calculated.

From the equation from Strength of Materials are calculated the stresses at the location of each instrument used for taking observations of axial stress for two total loads, (1) equal to the maximum allowable load and (2) one-half of the maximum allowable. The beam is then subjected to these two loading conditions, for which strain readings are made. Upon the assumption of a reasonable value for the modulus of elasticity (say that obtained in Experiment 1), the stresses in all cases of longitudinal strain are found. A comparison is made of the values of stress obtained by the two methods.

The instrument placed laterally is designed to detect the effect due to Poisson's ratio. The relation between strain in this direction with axial strain gives us the value of Poisson's ratio for the material of the beam.

Sketches are made of the cross section of the beam showing the warping effect according to Poisson's ratio and also showing graphically the distribution of stress along the depth of the beam.

Another part of the experiment utilizes a small rectangular steel beam under pure bending, seen in Figure 5. The deflection and axial curvature at the central section are measured by means of an Ames dial. The curvature in the lateral direction is measured by two mirrors attached to the sides of the beam, a telescope and scale.*

The set up is studied and a record is made of the necessary dimensions of the system. The elastic line, shear and bending moment diagrams are drawn. The maximum allowable load that can be applied is calculated.

* Batson and Hyde, *Mechanical Testing*, Vol. I, pp. 215–218. Carrington's Beam Experiment.

Several equal increments of dead load are applied at each end of the beam and readings are taken to determine the axial and the lateral curvature. It is noted that under pure bending the beam assumes the shape of a circular arc. The value of Poisson's ratio for the material of the beam is determined as the ratio of the axial radius of curvature to the lateral radius of curvature.

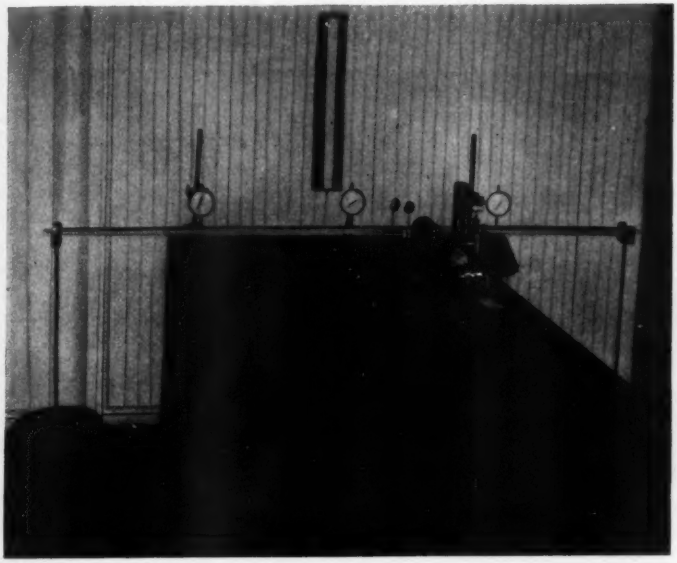


FIG. 5. Rectangular Steel Beam for Investigating the Curvature and Poisson's Ratio.

Experiment VII

The two parts of this experiment of the statically determinate problem in the bending of beams permit the determination of angles of rotation, deflection and the modulus of elasticity and the study of the Law of Superposition and the Reciprocity Theorem.

A cantilever beam is first investigated, Figure 6. The beam is steel of $\frac{3}{8}'' \times 1\frac{1}{2}''$ rectangular cross section and 48″ free length, clamped at one end. The student studies the set up, makes sketches and measurements of the system and constructs the shearing force and bending moment diagrams. The safe load that can be placed at the outer end is calculated.

The angles of rotation and deflections are calculated for two

points of the beam, namely the midpoint and the free end for several increments of load up to the safe amount placed separately first at the midpoint and at the end. A value of the modulus of elasticity of 29×10^6 lbs. per sq. in. is assumed.

These calculations then receive experimental verification by imposing the increments of load upon the beam and reading the angles of rotation and the deflections by use of Michigan dials.

The experimental data of load against deflection is plotted on

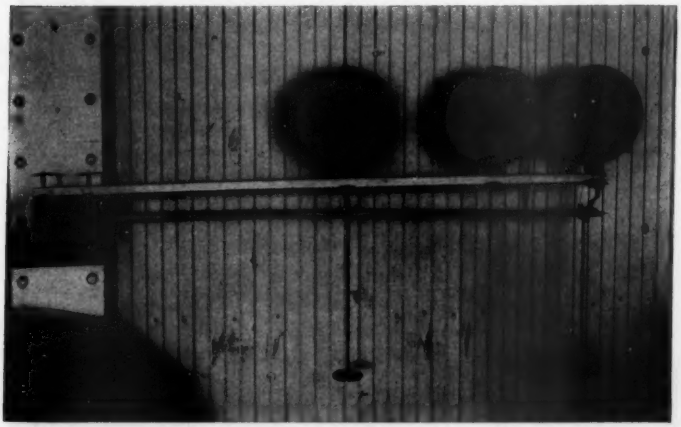


FIG. 6. Steel Cantilever Beam for Investigating the Angles of Rotation and Deflections.

one curve sheet. The coincidence of two of the curves illustrates the Reciprocity Theorem—Maxwell's Law.

The modulus of elasticity of the material of the beam is calculated from the plotted experimental data on the deflection at the outer end produced by loads at the outer end.

About one-half of the maximum allowable load used above is placed each at the midpoint and the free end. By calculations and experiment to determine the deflections, the validity of the Law of Superposition is shown for this particular case.

The second part of the experiment deals with a simply supported beam of approximately the same dimensions as above.

The same procedure is followed, except the points of the beam involved are the midpoint and quarter point.

Experiment VIII

The final experiment treats the statically indeterminate problem of a beam on three supports in which the load on the redundant support is investigated. The beam is steel of $\frac{3}{8}'' \times 1\frac{1}{2}''$ cross section by 84" long. Three cases are studied.

The first is the symmetrical case. Simple supports are placed at each end of the beam. At the midpoint is placed an upward reaction designed in such a manner that the force can be adjusted by adding dead weights to a mechanical lever system. The deflection at this redundant support is maintained zero as indicated on a Michigan dial similar to those used in previous experiments. The beam is loaded by two equal amounts at the two quarter points.

For the above conditions calculations are made which relate the amount of the two equal loads and the reaction at the redundant support.

These calculations are verified by experiment by placing equal loads at the quarter points and adding suitable weights at the redundant reaction so as to provide zero deflection.

The second part is a study of the general case where the various dimensions and loads of the system are unlike. The same procedure as described above is observed.

The last part considers a beam on three supports with an overhang. A single load is placed at the outer free end of the beam The adjustable redundant support acting downwards is placed between the two simple stationary supports. The deflection, again, at the redundant support is maintained zero. Analytical and experimental methods are used also for this problem.

Conclusion

It has been the intent of the course to give the student a clear picture of the mechanical properties of materials and the elementary engineering structures by suitably combining experiments, lectures and demonstrations which deal with basic considerations.

By preparing and conducting the program of this experimental course so as to parallel the theoretical course in the Strength of Materials, the student is able to establish a rational balance between these two phases of the subject. Confidence in the theory, moreover. is strengthened by the results of simple experiments.

Lastly, the student is introduced to some of the more important recent research methods and apparatus used in studying the physical properties of materials. He may appreciate, then, that further problems in this broad field of the Strength of Materials may be investigated.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

Executive Committee Meeting. The Executive Committee of the Division of Engineering Drawing met at Purdue University, December 21st and 22d, 1932. The following members of the committee and visitors were present: Harry M. McCully, Chairman; Justus Rising, Secretary; Thomas E. French; Clair V. Mann; William G. Smith; H. H. Jordan; and F. G. Higbee. Dean A. A. Potter of Purdue also met with the committee during its Thursday afternoon session.

In addition to hearing progress reports on the development of the program for the division at the annual meeting in June and to agreeing upon a general program policy for this meeting (program in detail to appear on this page at a later date), the committee

1. Viewed several reels of motion picture film produced by Rising of Purdue and designed especially to aid in the teaching of the manipulative technic of drawing. Not only did the films indicate that this new teaching device in drawing can be used to advantage but also that it opens a hitherto unexplored field in the teaching of drawing.
2. Heard a detailed report from Mann of the Missouri School of Mines on recent developments in the testing field. Not only were the several prominent tests on aptitude in drawing reviewed but comparisons between the testing and academic performance were available.
3. Discussed in detail the specifications and policies to govern the 1933 competition in Engineering Drawing (see February T-Square Page), and appointed the following Committee on Competition for 1933: Russell A. Hall, Union College; Frederic W. Ming, Brooklyn Polytechnic Institute; Earl C. Willey, Oregon State Agricultural College; Stanton E. Winston Armour Institute of Technology; and F. G. Higbee, Chairman, University of Iowa.
4. Informally discussed the responsibility of the Engineering Drawing Department in relation to the orientation of engineering students.

Following the adjournment of the meeting, considerable progress is to be reported both with respect to orientation as a responsibility and an opportunity for drawing departments, and to plans for the annual meeting.

NEW MEMBERS

BURNS, FRANCIS J., Instructor in Engineering Drawing, Newark College of Engineering, Newark, N. J. S. Fishman, H. N. Cummings.

CALVERT, SIDNEY, Professor of Chemistry, University of Missouri, Columbia, Mo. Jas. R. Lorah, Harry Rubey.

DULING, HUGO B., Associate Professor of Electrical Engineering, Georgia School of Technology, Atlanta, Ga. T. W. Fitzgerald, J. E. McDaniel.

FOOTE, JAMES H., Supervising Engineer, The Commonwealth & Southern Corporation, Consumers Power Co. Bldg., Jackson, Mich. Floyd A. Nagler, F. L. Bishop.

FULMER, HERMAN K., Associate Professor of Mathematics, Georgia School of Technology, Atlanta, Ga. J. E. McDaniel, R. S. King.

GOOD, MERRILL R., Professor and Head, Department of General Engineering, Montana State College, Bozeman, Mont. R. T. Challender, W. M. Cobleigh.

HARRISON, JAMISON R., Assistant Dean, Tufts College, Tufts College, Mass. George P. Bacon, Frederic N. Weaver.

JOHNSON, RUBEN G., Associate Professor of Civil Engineering, University of South Carolina, Columbia, S. C. Thos. F. Ball, W. S. Rodman.

LABREE, FRANK H., Instructor in Electrical Engineering and Physics, Northeastern University, Boston, Mass. C. S. Ell, W. C. White.

LEAVITT, ERNEST E., Instructor in Mechanical Engineering, Tufts College, Tufts College, Mass. Edgar MacNaughton, W. E. Farnham.

MORTON, ALLAN B., Professor of Mathematics, Georgia School of Technology, Atlanta, Ga. J. E. McDaniel, R. S. King.

REPSCHA, ALBERT H., Instructor in Mechanical Engineering, Drexel Institute, Philadelphia, Pa. Wm. J. Stevens, J. Harland Billings.

SUMWALT, ROBERT L., Professor of Civil Engineering, University of South Carolina, Columbia, S. C. Thomas F. Ball, W. S. Rodman.

109 new members this year.

COLLEGE NOTES

Bucknell University.—As a part of the general plans for the reorganization of departmental units and curricula programs, the various branches of Engineering, namely, chemical, civil, electrical and mechanical engineering, have been organized into a single administrative unit with a chairman for the group. Dr. S. C. Ogburn, Jr., formerly head of the department of Chemical Engineering, has been appointed by the President of the University as Chairman, and Dr. D. M. Griffith, formerly head of the department of Civil Engineering, has been selected as Secretary of the group.

The readjusted and unified course of studies leading to the bachelor's degree in the respective engineering fields is distributed over four years and one summer session and is in harmony with the current trends of higher education in the United States, and is designed to meet modern demands for training in these fields. In addition to the necessary and fundamental engineering training, it offers the student an opportunity for broad cultural education necessary to equip him for good citizenship and effective social living.

The work of the first two years is largely devoted to the study of fundamental tool subjects which form the basis for the professional courses given during the last two years of his program; and, to the pursuit of those studies which widen his cultural background. The first year's work is the same for all engineering students. It includes chemistry, drawing, and mathematics together with the freshman survey courses in English literature and the History of Western Man. The second year is devoted to the common preparation courses in physics, mathematics, mechanics; to specific preparation courses for the engineering curricula selected; and, to the sophomore survey courses in the Principles of Economics and the Evolution of Modern Social Institutions.

The summer session for chemical engineers is given between the junior and senior years at which time the course in unit operations and the principles of chemical engineering is given. For each of the other engineering groups the summer session is given between the sophomore and junior years. At this time the civil engineers take field work in surveying; and the electrical and mechanical engineers take direct current machinery and machine shop.

The last two years consists principally of professional subject matter given in the respective groups, together with elective courses

which may be taken either in fields related to their major line of study or to such subjects as psychology, philosophy or political science, or both. The professional work is designed to instruct the student in the principles and methods of the engineering group concerned so that the graduate may be qualified to enter the industrial activities usually pursued by that profession, or to enter upon a graduate program.

Clemson College.—In spite of the serious financial situation, Clemson College is carrying on as usual, with fine spirit on the part of both the student body and the faculty. The enrollment is substantially the same as last year with some gain in the upper classes and a slight decrease in the first year group. The attitude of students toward their work appears to be more serious than in better times.

During the past year several members of the faculty have received advanced degrees. J. H. Sams, Jr., Assistant Professor of Mechanical Engineering received the degree Master of Science in Mechanical Engineering at the end of a year's leave of absence spent in graduate study at the University of Michigan; D. D. Curtis, Professor of Mechanics and Hydraulics, received the degree Master of Science following graduate study and hydraulic research in summer sessions at the University of Iowa; E. L. Clarke, Professor of Civil Engineering, was granted the degree Civil Engineer by the University of Illinois; S. B. Earle, Dean of Engineering and Professor of Mechanical Engineering, was awarded the honorary degree LL.D. by Furman University.

Dean Earle has recently been elected President of the South Carolina Engineering Society, and Chairman of the Engineering Section of the Land Grant Colleges Association.

A new division of Drawing and Designing has been created with W. W. Klugh, Professor of Drawing, in charge. The work was formerly under Professor Klugh's direction but nominally in the Division of Architecture and Drawing.

The College's first Engineering-Architecture Day was celebrated last spring. Features were an exhibition by all divisions of engineering and architecture and a pageant for which scenery showing the development of architecture and slides showing the development of engineering were prepared by students. General Electric, Westinghouse, Bell Telephone, and others loaned equipment and exhibits which supplemented the displays in the college laboratories. The success of the endeavor exceeded expectations. Since Clemson is only a college community with no city close, it was felt that attendance might be small. But large crowds visited all features of the day, many coming from considerable distance.

Massachusetts Institute of Technology.—In continuation of its previous policy, the Massachusetts Institute of Technology is offering eighteen free courses during the second term for the benefit of unemployed engineers and architects. These courses include Accounting, Civil Engineering, Electrical Engineering, Geology, Materials of Engineering, Production Methods, Refrigeration, Reinforced Concrete Design, Soil Mechanics, and the Theory of Structures.

Ivan A. Getting, '33, Edison prize winner and Captain of Technology's gymnasium team, has been awarded a Rhodes scholarship for study at Oxford University during the next two years with the privilege of a third year if his scholastic achievements warrant it. Mr. Getting is the third M. I. T. man to be a Rhodes scholar.

On an isolated spot in East Machias, Maine, the new Technology seismograph is now in operation. It is the most easterly such instrument in North America. Because of its remoteness from the artificial disturbances of cities, and because it rests upon a foundation of ancient volcanic rock, in a zone of many geologic faults, the observations made by this station are expected to be of unusual interest. Neighboring stations are at Cambridge, Massachusetts and Ottawa, Canada.

University of Nebraska.—The first Engineering Experiment Station circular of the University has been put into the mails, under the date of Dec. 1, 1932. It is entitled "Comfort and Economy in Heating the Home, Using Coal or Coke as Fuel." The author is Professor Jiles W. Haney, Chairman of the Department of Mechanical Engineering.

At the invitation of the Joslyn Memorial, of Omaha, the Department of Architecture of the University of Nebraska has arranged an extensive exhibit of student work, remaining in place during the month of February.

The College of Engineering recently sponsored a one-day safety meeting attended by city electricians, town marshals, fire chiefs, councilmen, and others concerned in the safety of electrical installations.

The principal speaker was Victor H. Tousley, Electrical Field Engineer for the National Fire Protective Association.

A special faculty committee under the chairmanship of Professor W. L. DeBaufre, is initiating a study of the effects upon a student's work of conditional entrance, irregular schedules, heavy programs, etc. Attempts will also be made, in examining records, to discover any subject correlation which may appear.

Another study is proposed whose objective is a clearer recognition of the minimum requirements of certain subjects, and the

interrelations of various courses, their overlay and their carry-over values.

Northeastern University.—A new Business Administration laboratory has just been completed for the use of Business Administration and Industrial Engineering students. The physical equipment of the laboratory was designed and constructed by co-operative students in the School of Engineering. The laboratory is equipped with several Monroe and Marchant calculating machines of both hand operating and electrically driven types, adding machines, duplicating machines and other commonly used office equipment. This equipment will be used for laboratory work in statistics and for the computations incident to thesis work.

Professor Stanley G. Estes, Chairman of the Department of Psychology and Sociology at Northeastern, is offering a course in mental hygiene for unemployed "white collar workers" in Boston. This course is one of a number offered by the members of local university faculties for the purpose of sustaining morale during the economic depression.

Philip C. Nash, formerly Director of Engineering Practice at Northeastern, later Dean of Antioch College, and now Director of the League of Nations Association, was a recent visitor and lecturer at Northeastern University where he spoke before the entire Day Division student body in Jordan Hall on the work of the League of Nations Association.

Dean Carl S. Ell, Professor Henry B. Alvord, and Professor James W. Ingalls of the Engineering School faculty, are planning to attend the fortieth anniversary meeting of the S. P. E. E. in Chicago next June. Professor Alvord will present a paper on "Co-operative Education" to the Coöperative Colleges Division of the S. P. E. E.

Stevens Institute of Technology.—Professor Louis Alan Hazeltine, inventor of the radio neutrodyne, returned from France on the S. S. *President Hayes* to re-enter the faculty of Stevens Institute of Technology as Professor of Physical Mathematics, after an absence of seven years spent in mathematical studies, chiefly abroad. At the time of his invention of the neutrodyne, which dramatically changed the radio industry, Mr. Hazeltine was professor of electrical engineering on the Stevens faculty but he resigned his chair in 1925 when he is reported to have said that the commercial success of his invention would permit him to devote his time exclusively to mathematics. The formidable task which he then set for himself was that of reducing mathematical knowledge to a comprehensive system for teaching purposes, beginning with simple arithmetic and

going through to the graduate level. Under his new appointment at Stevens, he will offer courses in the graduate department but will also give one undergraduate course in Mathematics for freshmen entering college in February.

Tulane University.—The rehabilitation of the Chemical Engineering Laboratory has been completed and is now equipped with excellent facilities for the demonstration and critical study of the Flow of Fluids, Flow of Heat, Separation of Materials, Drying, Distillation, Humidification, Evaporation and other processes. A complete small boiler plant has been installed, so that the laboratory may have live steam available at all times.

The Department of Electrical Engineering is completing the construction and installation of a large high voltage air-condenser and auxiliary apparatus, which will be used for research upon problems of insulation of cables, under the direction of Assistant Professor P. H. Humphries.

SECTIONS AND BRANCHES

President Seaton has visited the following Sections this year:

The Kansas-Nebraska Section meeting at the University of Nebraska October 28 and 29, 1932. At this meeting he did not deliver any prepared address, but spoke extemporaneously at the business meeting and again at the luncheon, both on October 29.

The organization meeting of the Pacific Southwest Section at the California Institute of Technology December 29, 1932. Here he gave the response to the address of welcome and spoke extemporaneously at the dinner and at several of the business sessions.

The Missouri Section meeting at the Missouri School of Mines January 6 and 7, 1933. Here he presented a paper on post-graduate study in engineering.

The South Dakota Section meeting at Aberdeen, South Dakota, January 12, 1933. He gave here the same address on postgraduate study in engineering as was given at the meeting of the Missouri Section. On invitation by President Anderson of the State Normal School at Aberdeen, he also addressed the student assembly of that institution on the subject "The Work of the Engineer."

At all of the section meetings he attended, he emphasized the importance of sectional meetings in the work of the Society and called attention to the rapid growth in importance of this phase of the Society work. He also called attention to the next annual meeting of the Society to be held in Chicago and urged all section members to attend this meeting.

The **Georgia School of Technology Section** of the S. P. E. E. held its second meeting February 16th. Thirty-two members of the faculty of Georgia Tech were present. The paper presented was entitled "The Ideal Electrical Engineering Course," by Professor T. W. Fitzgerald, Head of Electrical Engineering. The paper was very interesting and aroused considerable interesting discussion. At this meeting consideration was given to the possibility of Regional Meeting being held in Atlanta at some later date.

R. S. KING,
Secretary.

POST GRADUATE STUDY IN ENGINEERING

By R. A. SEATON, President S.P.E.E.

Address given at the Missouri Section Meeting at Rolla, Jan. 6, 1932, and at the South Dakota Section Meeting at Aberdeen, Jan. 12, 1933.

It has not been very many years since less than half of the members of the national engineering societies in America held degrees from engineering schools. The other members had had little or no formal technical training, but through experience, through working with and under the direction of other engineers, and through self education they had learned the essentials of the work of their profession. They had grown into the profession, coming up through the ranks. College training for engineering was, in earlier years, even looked upon with suspicion, and the engineering graduate, fresh from college, was wise if he kept to himself the fact that he had been through college.

More recently, all of this was changed. The college trained engineer made good, and it became generally recognized that engineering training is the quickest, surest, most direct, and most economical method of entering the engineering profession. Industries generally recruit their young engineers from the graduates of engineering colleges, and relatively few men in these days enter engineering work without a collegiate engineering training. While still many of the older members of the engineering societies have come up through the ranks, nearly all of those who have joined these societies in recent years have entered the profession through the engineering colleges.

The situation has developed to a point where the industries and the public look to college trained engineers to carry on not only those activities which are in the strict sense of the term, professional engineering, but also many allied activities which are commercial or administrative in character, but which deal with engineering products or engineering processes.

The field of engineering has, in recent years, become much broader and more complex, too, through new discoveries in the basic sciences and through new applications of these discoveries which have lead to the division, the subdivision and the re-subdivision of the various branches of the field. Civilization today has become intensely and extensively industrialized, while the field of the engineer has become as broad as that of industry, which is to say as broad as civilization itself. One of the outstanding phenomena of recent times is the extent to which the work and the products of the work of the engineer enter into the daily activities of all the people of all the civilized world.

Up to the present time the engineer has devoted his energies chiefly to the problems of production and he has been eminently successful in the solution of these problems. We can now produce easily with existing plants, equipment, and personnel enough of everything to satisfy the material needs of everybody. *For the first time in the history of civilization* it is now possible to produce enough for everybody. We may say therefore that the engineer has completely solved the problem of production.

But the public is not satisfied. There is much talk of technological unemployment and the engineer is being blamed for the very thoroughness and completeness with which he has solved the problems of production. Apparently we now have too much of everything—too much steel, too many automobiles, too much oil, too much cotton, too much wheat, too many oranges, too much food, all because of the use of machinery and power and the quantity methods of production developed by the engineer. Because we have too much of everything, people are out of work and are unable to buy and hence must do without those very things of which there is a surplus. We do not really have too much of anything, but only more than can be utilized under our clumsy and antiquated methods of economic distribution of the products of our labors. The demand now arises that the engineer shall attack and endeavor to solve the problems of economic distribution, as he has attacked and solved the problems of production.

And so the work of the engineer constantly becomes more and more complex and is ever being broadened and extended into new fields, and the difficulty of providing adequate training for work in this field becomes constantly greater. The problems of engineering education must be studied and restudied, and curricula, courses, and methods must be constantly revised to keep pace with new developments in the engineering field in order to give our students the very best possible preparation for their professional work.

Throughout the history of college engineering training in America, the period devoted to this work has been practically standardized at four years. Further, the standard of preparation of those entering upon the collegiate engineering training has advanced little or none in recent years. In fact it is believed by many that the standard of preparation is not so high now as it was fifteen to twenty-five years ago, on account of the general letting down of high school standards which is said to have accompanied the great increase in the number of pupils attending high schools, and the adaptation of high school courses to training for life rather than to training for college.

In an effort to keep pace with the development of the engineer-

ing field and of the fundamental sciences upon which enginering is based, engineering colleges have attempted to include more and more technical work in their curricula, until most of the courses of the earlier engineering curricula which were intended to be "broadening" and "cultural" have been eliminated and those which remain have for the most part been made more utilitarian in character. So much work has been crowded into the curricula and into the courses, too, that it does not seem possible to carry the crowding process further. And yet the training of the engineering graduate at the completion of his four year college course is pitifully inadequate for the higher phases of his professional work. He is in no wise a competent engineer, but has only laid the foundation for his engineering training, upon which the completed structure must be built later through further study, either organized or unorganized, through working under the direction of and learning from, competent practicing engineers, and through the development which comes from successful experience. The process of training after the college course is completed must still go on much as it formerly did for those who had no college training.

The question has often been raised as to whether the formal training in college could not advantageously be carried further than the four years, as is done in training for the professions of law and medicine. Several attempts have been made by different engineering schools to relieve the congestion of the engineering curricula and to carry the collegiate training for the engineering profession further by expanding the undergraduate engineering training to five years, but without any considerable degree of success. Most of such attempts have been abandoned—probably chiefly because very few students enrolled for the five year curricula—and the four year limit for undergraduate engineering training seems to be pretty definitely established. Further study and development must then be postgraduate, *i.e.*, secured after graduation, either in educational institutions or in industry.

I believe it is probably true that for the majority of engineering students, a four year course is all that can profitably be taken in college. For a considerable number, however, perhaps 25 per cent to 30 per cent of the graduates, including the highest grade students who have the ability and the ambition to develop into leaders in their professional work, I am convinced that another year or more of training in an educational institution is highly desirable.

I believe also that this additional training can and should usually be so planned that it will lead to the master's degree, with a small percentage of the students continuing to the doctor's de-

gree. The undergraduate engineering training has developed into more or less of a cramming process, with relatively little opportunity for the encouragement of independent thinking, for the development of special individual ability, or for directing the attention of the student toward investigation and research. Graduate work generally gives much freer opportunity in all of these directions, and under competent supervision this should be of great value in the training of the more capable students for leadership in the profession. There is a growing interest in graduate engineering study on the part of both students and colleges and in the last few years there has been a remarkable increase in the number of students enrolled for such work. While part of this development may be due to the employment situation, I believe the tendency toward more postgraduate work in engineering is a wholesome one and will continue.

If this postgraduate engineering training is to be most valuable, it is necessary for the engineering colleges that offer it to study the problems of postgraduate training most carefully and to make adequate provision for handling the work efficiently and well. The recent considerable increase in the number of graduate engineering students in many colleges has found some of these colleges quite unprepared to handle them adequately and much of the postgraduate training in engineering has not been as well done as it should have been done. While many factors are involved, two seem to me to be especially important—first, adequate preparation of the engineering faculty members who are to handle the graduate work, and second, adequate development of research activities in the engineering college.

It is very important, in my opinion, that the engineering teachers shall have, themselves, pursued postgraduate work leading to higher degrees, as well as that they shall have had sound professional or industrial experience. There seems to be a growing tendency for engineering colleges to require their instructors to secure a higher degree before they can be promoted to the professorial ranks, and in my opinion, this tendency must develop much further in the future, with the doctor's degree relatively common and the master's degree and sound professional experience the minimum requirements for the professorial rank in all the better engineering schools.

For the past three years, I have had the privilege of serving as chairman of the Committee on Engineering Research of the S. P. E. E. and in this capacity, have collected data on engineering research in the colleges and universities of North America. From a study of these data one is forced to the conclusion that comparatively few engineering colleges have developed an adequate pro-

gram of engineering research, such as is desirable and important for an extensive program of graduate study. Engineering research should, in my opinion, be much further developed in the colleges, not only for the value of the discoveries resulting from such research, but also for the value of such research in training engineering students, particularly postgraduate ones.

An excellent Progress Report on Graduate Study was presented at the Corvallis meeting of the S. P. E. E. last summer by the Committee on Graduate Study, through its chairman, Dean Kimball of Cornell. This report deals chiefly with the organization and administration of the work and is well worth careful study. It is, however, admittedly "preliminary and exploratory, only." Much study must still be given the many phases of the problems involved in postgraduate work, both by the engineering colleges and by the Society before this work can be considered to be on a definitely satisfactory basis, comparable with the present status of undergraduate engineering training.

In my opinion, the development of postgraduate study in engineering is one of the most important problems in engineering education at the present time, one full of promise for the welfare of humanity, and worthy of our most serious study.

Pacific–Southwest Section

RESPONSE TO THE ADDRESS OF WELCOME AT THE CALIFORNIA INSTITUTE OF TECHNOLOGY, DECEMBER 29, 1932

By R. A. SEATON, President S. P. E. E.

It is a great privilege and pleasure to hold the first meeting of the Pacific-Southwest Section under such happy conditions and in such delightful surroundings as offered by the California Institute of Technology. Southern California is famous the world over for its beauty and its romance, its climate and its hospitality, and nowhere are these more in evidence than in Pasadena, with its palms and its roses, its beautiful homes, and its educational institutions.

The Section is particularly fortunate, I think, in being privileged to meet at this Institute, with its many eminent scientists, both pure and applied, who have been so fruitful in their research efforts. Many years ago Francis Bacon divided all research into two classes which he called *lucifera*, or that which produces enlightenment, and *fructifera*, or that which bears fruit. At the present time the distinction is, perhaps, not so valid as it was in Bacon's time, and

pure science research may be quite as fruitful in the hands of the engineer as applied science research. It is the province of the engineer to apply all knowledge of the physical, social, and economic sciences, whether primarily enlightening or primarily useful, to the use and benefit of mankind. Here at the California Institute of Technology is a delightful example of splendid work in both pure and applied science, and we are all very grateful, I am sure, for the opportunity to hold our meeting at this institution.

The organization of the Pacific-Southwest Section of the S. P. E. E. marks a very distinct step forward in the work of the Society. It should be productive of a great deal of good for the cause of engineering education, not only in the territory served directly by the Section, but generally throughout the country as well. The meetings of this Section will bring to those of the Pacific-Southwest many of the benefits which the meetings of the parent Society bring to those who can attend them. Most of these meetings of the parent Society must of necessity be held in the east or in what people in the east call the middle west. The Section meetings will afford an opportunity for engineering educators in these western states to get together and discuss their problems, exchange their experiences, and become acquainted with each other. Many of the papers presented at these meetings will be published in the Journal of the Society and thus the benefit of your experiences, your thoughts, and your accomplishments in engineering education can be made available for those in other sections of the country.

The formation of this Section will greatly stimulate the interest of the engineering educators in this territory in the work of the parent Society. I believe it is true that, on the average, in those institutions included within the limits of Sections of the Society that have been active for several years, at least twice as large a percentage of members of the engineering faculties belong to the Society as belong in institutions not included in such Sections. I look forward confidently to the doubling or trebling of the Society membership in those southwestern institutions in the next few years as the result of the organization of this Section. Thus the Section will benefit engineering education in this region, not only directly through its own meetings and influence, but also indirectly through bringing the benefits of membership in the parent Society to more engineering teachers.

For many years I have been enthusiastic about the value of sectional meetings of the Society. My experience with them dates from 1920 when the Kansas-Nebraska Section was organized. This was one of the first, if not the first, Section of the Society to be organized. I had the privilege of serving it the first two years as secretary, and later as chairman. The membership and interest

have increased year by year, and at the latest meeting, held in Lincoln, Nebraska, a few weeks ago more than 150 were in attendance. More than 50 from my own institution, the Kansas State College, drove 140 miles to attend the meeting. The meetings of the Section have, I believe, been of very great value in stimulating our teachers and in improving the quality of engineering instruction in my institution, and in the other institutions served by the Section.

The formation of new Sections of the Society has been rapid in the past few years. The New England Section, the Middle Atlantic Section, the Ohio Section, the Kentucky Section, the Minnesota Section, the South Dakota Section and the Kansas-Nebraska Section have been functioning for several years. In the past three years new sections have been organized as follows: the Arkansas-Oklahoma Section, the Texas Section, the Missouri Section, the Colorado-Wyoming Section, the Pacific Northwest Section and the Pacific Southwest Section. Others will, no doubt, be organized in the not distant future. Some of these Sections will, no doubt, be of great value, while others may never accomplish much, and may eventually disintegrate. This will depend chiefly upon the energy, enthusiasm, and good judgment of the members of the sections and of the officers in charge, and the interest taken in them by the administrative officers of the institutions concerned. The responsibility for the successes or failures of the Sections rests with the members of the Sections.

The Pacific-Southwest Section has made an excellent start, and I know it will be a valuable asset to engineering education in the Southwest and in the country generally. I assure you that this new Section has the very best wishes of the parent Society and of the other sections already established.

The **South Dakota Section** of S. P. E. E. held its annual meeting at the Ward Hotel in Aberdeen, South Dakota, Thursday, January 12. In addition to the regular members of the Section, several out of state members of S. P. E. E. were with us. President R. A. Seaton and Asst. Dean M. A. Durland drove up from Manhattan, Kansas, to attend. Dean Dolve with four other members of the Engineering staff of North Dakota State College drove from Fargo, North Dakota, to attend the meeting.

The morning session was called to order at nine o'clock. Prof. E. E. Clark of the State School of Mines, President of the Section, presented a paper on "The Future of Engineering." Professor Blodgett of South Dakota State College presented a paper on "Engineering Teaching Methods." The paper "Engineering Graduates" prepared by Professor J. M. Brown of the University

of South Dakota was read by Professor Newcomb. The interest of the group in these papers was expressed by the discussions which followed each one.

At noon the meeting adjourned for dinner in the hotel dining room.

The meeting resumed at 1:15 at which time President R. A. Seaton presented his paper on "Graduate Students in Engineering." Dean H. M. Crothers of South Dakota State College then gave his paper on "Graduate Students in South Dakota." A general discussion followed these papers.

A short business meeting followed the program. Plans were discussed for the next year's meeting. Some valuable suggestions for our future meetings were given by President Seaton and Dean Durland when they told us of some of the experiences of other sections. After some discussion a motion was passed authorizing the officers to make arrangements for a fall or a spring meeting of the Section to be held at one of the member institutions.

Dean H. M. Crothers of the South Dakota State College invited the Section to hold its next meeting in Brookings.

The officers were also instructed to extend an invitation to the North Dakota schools inviting them to join with us in forming a new section.

The following officers were selected for the year 1933:

H. E. Brookman, University of South Dakota, President
Wm. H. Gamble, South Dakota State College, Vice-president
C. G. Wattson, S. D. School of Mines, Secretary-Treasurer

The meeting adjourned at 3:45.

LIST OF THOSE IN ATTENDANCE AT THE 1933 MEETING OF THE SOUTH DAKOTA SECTION OF S. P. E. E. HELD AT THE WARD HOTEL IN ABERDEEN, SOUTH DAKOTA, JANUARY 12, 1933

State School of Mines—Rapid City

Professor E. E. Clark — Mr. W. Walkling

University of South Dakota—Vermillion

Professor H. E. Brookman — Professor R. V. Newcomb

South Dakota State College—Brookings

Dean H. M. Crothers — Professor Wm. H. Gamble
Professor H. S. Carter — Mr. B. Aldrich
Professor J. T. Strate — Mr. Lowell Yost
Professor H. H. Hoy — Mr. Wm. Lowe
Professor H. B. Blodgett

Kansas State College—Manhattan

Dean R. A. Seaton — Asst. Dean M. A. Durland

North Dakota State College—Fargo

Dean R. M. Dolve
Professor L. O. Doerr
Professor Smith
Professor J. A. VanDyke
Mr. Yott

Visiting Engineers

Mr. Lester Hall — Mr. David Williams

PROGRAM

Sixth Annual Meeting

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

South Dakota Section

Aberdeen, South Dakota — January 12, 1933
Headquarters—Alonzo Ward Hotel

Thursday Morning, January 12, 1933

8:00 Registration of members and visitors
8:15 Meeting called to order by President E. E. Clark
Minutes of the meeting of 1932
Appointment of committees
8:30 The Future of Engineering Education
E. E. Clark, State School of Mines
President, S. D. Section, S. P. E. E.
Discussion—
Professor J. T. Strate, S. Dak. State College
9:30 Engineering Teaching Methods
Prof. H. B. Blodgett, S. Dak. State College
Discussion—
Prof. M. W. Davidson of University of S. Dak.
10:30 The Engineering Graduate
Prof. J. Maughs Brown, University of S. Dak.
Discussion—
Prof. H. E. Brookman, University of S. Dak.
11:30 Recess for noon

Thursday Afternoon

1:15 Post Graduate Study in Engineering
Dean R. A. Seaton, Manhattan, Kansas
National President, S. P. E. E.

2:15 Graduate Students in Engineering in South Dakota
Dean H. M. Crothers, S. Dak. State College
Discussion—
Prof. Harold B. Gotaas, University of S. Dak.

3:30 Business Session

4:00 Adjournment

BOOK REVIEW

An Outline of Atomic Physics, by Some Members of the Physics Staff of the University of Pittsburgh. John Wiley and Sons, 1933.

This book, designed for the serious, intelligent, college student, is the outcome of a series of lectures given to students who had completed one year of college physics and wished a view of the interesting new developments in the study of the atom. The book omits the long equations found in the usual atomic physics text, purely for students majoring in physics, and gives any serious student a fine view of the field.

There is a large amount of material in the text which may be omitted from the usual one year course, but on this account the book is excellent as a reference book.

After a short history of the various atomic theories, the latest are given in some detail, the quantum theory is dealt with, as well as spectroscopy and X-rays. There are also chapters on waves and corpuscles, molecular structure, radioactivity, relativity, and astrophysics.

The style of the book is excellent, all the subjects being covered in a uniformly simple and easily understood manner but without being wordy.

The authors are: O. H. Blackwood, Elmer Hutchisson, T. H. Osgood, A. E. Ruark, W. N. StPeter, G. A. Scott, and A. G. Worthing.

NECROLOGY

William Henry Creighton, U. S. N., Professor of Mechanical Engineering, *Emeritus*, died at his home in New Orleans, January 24, 1933, after a brief illness.

Professor Creighton was born in Cincinnati, Ohio, June 29, 1858. He received his early education in the public schools of his native city and was graduated from the United States Naval Academy in 1882. After several years of active duty in the Navy, he became one of a group of young naval officers who were assigned by the United States Government to Land Grant colleges as instructors in engineering. In this service, Professor Creighton was assigned to Purdue University, where he taught from 1887 to 1891. He then became Chief Engineer of the U. S. Coast Survey S. S. *Blake*, but owing to an affection of the throat which prevented his continuance of sea duty, he was retired from active service in 1892.

He was appointed to the position of Professor of Mechanical Engineering in Tulane University in October 1894 and served continuously in that capacity until his retirement in September 1932.

With the organization of the College of Engineering as a separate college in 1911, he was appointed Dean of the same and served until 1919, when he relinquished the position in order to devote his whole time to his teaching duties.

While he has won recognition as a consulting engineer, as a contributor to engineering journals and periodicals, and as the author of a standard text-book on the "Steam Engine," Professor Creighton's distinct contribution to the College of Engineering of Tulane University has been his outstanding ability as a teacher. Always a strict disciplinarian and exacting the highest standard of accomplishment from his students, he was possessed of a sympathetic understanding of their difficulties and had developed methods of instruction which, from practically unanimous testimony of his students, have been of the greatest value to them, not alone in college but in the subsequent practice of their profession.

Professor Creighton was retired on a Carnegie pension at the close of the session of 1931–32, but in accordance with a recent ruling of the Carnegie Foundation he was retained in active service for a few hours of class work each week in his favorite subject of "Strength of Materials."

He was a member of the Society of Naval Engineers, the Society for the Promotion of Engineering Education and the Louisiana Engineering Society.

Prof. David P. Gilmore, died January 13, 1933. He came to the University of Detroit in 1925 to head the Civil Engineering department of the College of Engineering.

At the time of his arrival at the University there were approximately 30 students enrolled in the Civil Engineering department. However, under the consistent supervision of Prof. Gilmore the enrollment steadily increased until a total of over 100 students had been reached.

Courses in Railroad Surveying, Sanitary Engineering, Structural Design and Highway Engineering, advanced greatly under the direction of Prof. Gilmore until they had reached as high a standard as the same courses in the leading universities of Engineering in the country. During his régimé here, he has expanded and improved the various other courses offered under Civil Engineering, he has increased the hours, secured better text books, and as a whole has raised the rating of the department.

He was instrumental in establishing the University of Detroit Civil Engineering Society, and secured many members of the faculty to join the national organization of the Society for the Promotion of Engineering Education, of which he was the University representative. He was also a member of the American Society of Civil Engineers.

Prof. Gilmore was born in Arnot, Pa., May 6, 1885. He received his Bachelor of Science degree at Pennsylvania State College and his M.S. degree at the University of Iowa, where he spent 11 years as associate professor of Civil Engineering before coming to the University of Detroit.

Dr. William Lispenard Robb, Professor of Electrical Engineering and Physics and Head of the Department of Electrical Engineering at Rensselaer Polytechnic Institute, died on January 26, 1933, at Troy, N. Y. He was born on May 9, 1861, at Saratoga Springs, N. Y. His early education was obtained in the schools of Saratoga Springs, after which he entered Columbia University, graduating with the degree of Bachelor of Arts in the class of 1880. Dr. Robb was awarded a Columbia University Fellowship and was one of the first of the young American students to go abroad to study science. He spent two years at the University of Wurzburg and, after another year at study at the University of Berlin, was given the degree of Doctor of Philosophy by the latter institution in 1883. In Germany, Dr. Robb studied under such eminent physicists as Kohlrausch, von Helmholtz and Kirchoff. Returning to America, Dr. Robb became Assistant Professor of Mathematics in the School of Mines at Columbia University. In 1885, he accepted the chair of Physics at Trinity College, Hart-

ford, Conn., and served at that institution for 17 years, except for brief intervals spent in travel and in government service during the Spanish-American War, when he was in charge of mine laying in New York harbor. In 1892, Dr. Robb returned to Europe to spend a year in study at the Federal Polytechnic Institute at Zurich, Switzerland. In 1902, he was honored with the degree of LL.D. from Trinity College and in the same year went to Troy to form the Electrical Engineering Department at Rensselaer Polytechnic Institute. He was head of that department at the time of his death. In 1932 he was given the honorary degree of Doctor of Engineering by Rensselaer Polytechnic Institute. Dr. Robb played a prominent part in the development of the electrical industry in this country, especially in the public utility field. He was well known as a consulting engineer and was associated in that capacity with the New York Shipbuilding Corporation, the General Electric Company, the Aluminum Company of America, the General Railway Signal Company and the Hartford Electric Light Company. He served the latter company for more than 35 years, and was still active in its employ at the time of his death. Dr. Robb was a member of the American Physical Society, the New York Academy of Sciences, the Delta Phi and Phi Beta Kappa Fraternities, the Society of the Sigma Xi, the Engineer's Club and the Troy Club. He was an honorary member of the Rensselaer Society of Engineers and a former trustee of the Troy Public Library.

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